DOCUMENT RESUME

ED 148 823 95 SP 012 119

AUTHOR Klausmeier, Herbert J.; And Others
TITLE First Year of Intervention Study to Facilitate Children's Concept Learning. Technical Report No. 424.
INSTITUTION Wisconsin Univ., Madison. Research and Development Center for Cognitive Learning.
SPONS AGENCY National Inst. of Education (DHEW), Washington, D.C.
PUB DATE Mar 76
CONTRACT NE-C-00-3-0065
NOTE 130p.; For related documents, see SP 012 116

EDRS PRICE MF-$0.83 HC-$7.35 Plus Postage.
DESCRIPTORS *Concept Formation; *Educational Research; Elementary Education; Individualized Instruction; *Observational Learning; *Process Education; *Science Education
IDENTIFIERS *Concept Learning

ABSTRACT

Theory and research regarding four levels of concept attainment and three uses of concepts as specified by the conceptual learning and development (CLD) model are described. The strategy of a longitudinal intervention study is detailed. This study is designed to determine the effects of implementing both the model of instructional programming for the individual student (IPM) and specially prepared lessons based on the CLD model. These lessons were designed to teach the process-concepts of science that are incorporated in the curricular program "Science: A Process Approach." The results of a short-term experiment conducted to assess the effectiveness of a lesson on the process-concept, "observing scientifically," are also reported. (Author)

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Technical Report No. 424

FIRST YEAR OF INTERVENTION STUDY TO FACILITATE CHILDREN'S CONCEPT LEARNING

by

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and Michael L. Brumet

Report from the Project on
Conditions of School Learning and Instructional Strategies

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March 1976
Reprinted December 1977

SP 012 119

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Center Contract No. NE-C-00-3-0065

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- providing assistance to educators which helps transfer the outcomes of research and development to improved practice in local schools and teacher education institutions

The Wisconsin Research and Development Center is supported with funds from the National Institute of Education and the University of Wisconsin.

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ACKNOWLEDGMENTS

The authors wish to acknowledge the cooperation and assistance provided by F. R. Holt, Superintendent of Schools, L. Loofboro, Director of Elementary Education, and H. Haag, Science Coordinator, from the Janesville, Wisconsin, Public School System.

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ABSTRACT

Theory and research regarding four levels of concept attainment and three uses of concepts as specified by the conceptual learning and development (CLD) model are described. The strategy of a longitudinal intervention study is detailed. This study is designed to determine the effects of implementing both the model of instructional programming for the individual student (IPM) and specially prepared lessons based on the CLD model. These lessons were designed to teach the process-concepts of science that are incorporated in the curricular program Science: A Process Approach. The results of a short-term experiment conducted to assess the effectiveness of a lesson on the process-concept observing scientifically are also reported.

I

INTRODUCTION: CONCEPTS AND CONCEPT LEARNING

Individuals at all levels of human development are constantly learning new concepts and extending and using old concepts in new situations. It is apparent, however, that a person's level of mastery of a particular concept will vary depending upon his or her experiences with concept instances and ability to perform the cognitive operations. For example, a four-year-old child and a biologist may both have a concept of tree; although both may perform equally well when asked to identify a few obvious examples and nonexamples of tree, their concepts differ markedly. Despite the large difference in level of understanding, concepts are the fundamental agents of thought for human beings from early childhood through adulthood.

A substantial amount of research on concept learning has been completed during the past two decades dealing with the internal and external conditions of concept learning. Content analyses of concepts and behavioral analyses of concept learning related to various subject-matter fields have also been conducted. Sufficient knowledge has accrued so that Klausmeier, Ghatala, and Frayer (1974) were able to formulate a model that specifies and describes the cognitive operations involved in the attainment of concepts at specifiable

levels of mastery by individuals whose abilities change in predictable ways with age. (We use "age" as a shorthand term to indicate the product of learning and maturation; age, per se, is not considered a determining factor of how well individuals can perform.)

An analytical descriptive model of conceptual learning and development (CLD model) was initially formulated by Klausmeier (1971) and described more fully by Klausmeier, Ghatala, and Frayer (1974). The model defines four levels of concept attainment and the possible uses and extensions of attained concepts, specifies the cognitive operations involved in learning concepts at each of the four levels, and postulates internal and external conditions of learning related to the specified levels. The levels of concept mastery, the operations, and the conditions of learning have been identified through content analyses of concepts and behavioral analyses of concept learning tasks, and through empirical research in laboratory and school settings carried out at the Wisconsin Research and Development Center for Cognitive Learning and other research laboratories.

THE NATURE OF CONCEPTS

The word concept is used by Klausmeier, Ghatala, and Frayer (1974) to designate mental constructs of individuals and also identifiable public entities that comprise part of the substance of the various disciplines. Thus, concept is used appropriately in two different

contexts just as many other English words are. A concept is defined as ordered information about the properties of one or more things--objects, events, or processes--that enables any particular thing or class of things to be differentiated from, and also related to, other things or classes of things.

In regard to concepts as mental constructs, it is noted that maturing individuals attain concepts according to their unique learning experiences and maturational patterns. In turn, the concepts that are attained are used in the individual's thinking about the physical and social world.

Concepts as public entities are defined as organized information corresponding to the meaning of words. Carroll (1964) related concepts, words, and word meanings in the following way. Words in a language can be thought of as a series of spoken or written entities. There are meanings for words that can be thought of as standards of communicative behavior shared by those who speak a language. Finally, there are concepts--that is, the classes of experiences formed in individuals either independently of language processes or in close dependence on language processes. Putting the three together, Carroll stated: "A 'meaning' of a word is, therefore, a societally standardized concept, and when we say that a word stands for or names a concept it is understood that we are speaking of concepts that are shared among members of a speech community (1964, p. 187)."

At the inception of a large programmatic research effort dealing with concept learning and instruction, Klausmeier, Davis, Ramsay, Fredrick, and Davies (1965) formulated a conception of concept in terms of defining attributes common to many concepts from various disciplines. Klausmeier, Ghatala, and Frayer (1974) further refined the definition by specifying eight attributes of concepts: learnability, usability, validity, generality, power, structure, instance numerousness, and instance perceptibility. Other researchers and subject-matter specialists are also treating concepts in terms of defining attributes. For example, Flavell (1970) indicated that a formal definition of concept in terms of its defining attributes is useful in specifying what concepts are and what they are not and also in identifying the great variability among concepts. Markle and Tiemann (1969) and Tennyson and Boutwell (1971) have shown that the external conditions of concept learning can be delineated through research that starts with a systematic identification of the defining attributes of the particular concepts used in the research. Scholars at the Wisconsin Research and Development Center demonstrated that analysis of concepts in terms of their defining and variable attributes is useful in clarifying the meanings of the concepts drawn from four disciplines: language arts--Golub, Fredrick, Nelson, and Frayer (1971); mathematics--Romberg, Steitz, and Frayer (1971); science--Voelker, Sorenson, and Frayer (1971); and social studies--Tabachnick, Weibble, and Frayer (1970).

The CLD model deals primarily with concepts represented by words that can be defined in terms of attributes. However, some concepts are defined on other bases, including synonyms and antonyms. Further, not all words potentially definable in terms of attributes are so defined, even in unabridged dictionaries. Therefore, the researcher and also the developer of curriculum materials must ascertain the defining attributes independently or cooperatively with scholars from the various disciplines.

AN OVERVIEW OF THE CONCEPTUAL LEARNING AND DEVELOPMENT MODEL

Figure 1 shows the structure of the CLD model. Four successively higher levels in the attainment of a given concept are outlined. The four levels are concrete, identity, classificatory, and formal. As a concept is attained by an individual at the successive levels, it becomes increasingly usable and valid, as defined earlier.

A second part of Figure 1 shows the ways in which concepts may be extended and used. Concepts acquired at only the concrete and identity levels can be used to solve simple problems that require only the relating of obvious sensory perceptions. For example, to save time or for some other reason, children may walk diagonally across a rectangular block rather than remaining on the sidewalk and walking around a corner of the block. They need not have attained the concepts of distance, angle, diagonal, or straight line at the classificatory level.

Concepts acquired at the classificatory and formal levels may be

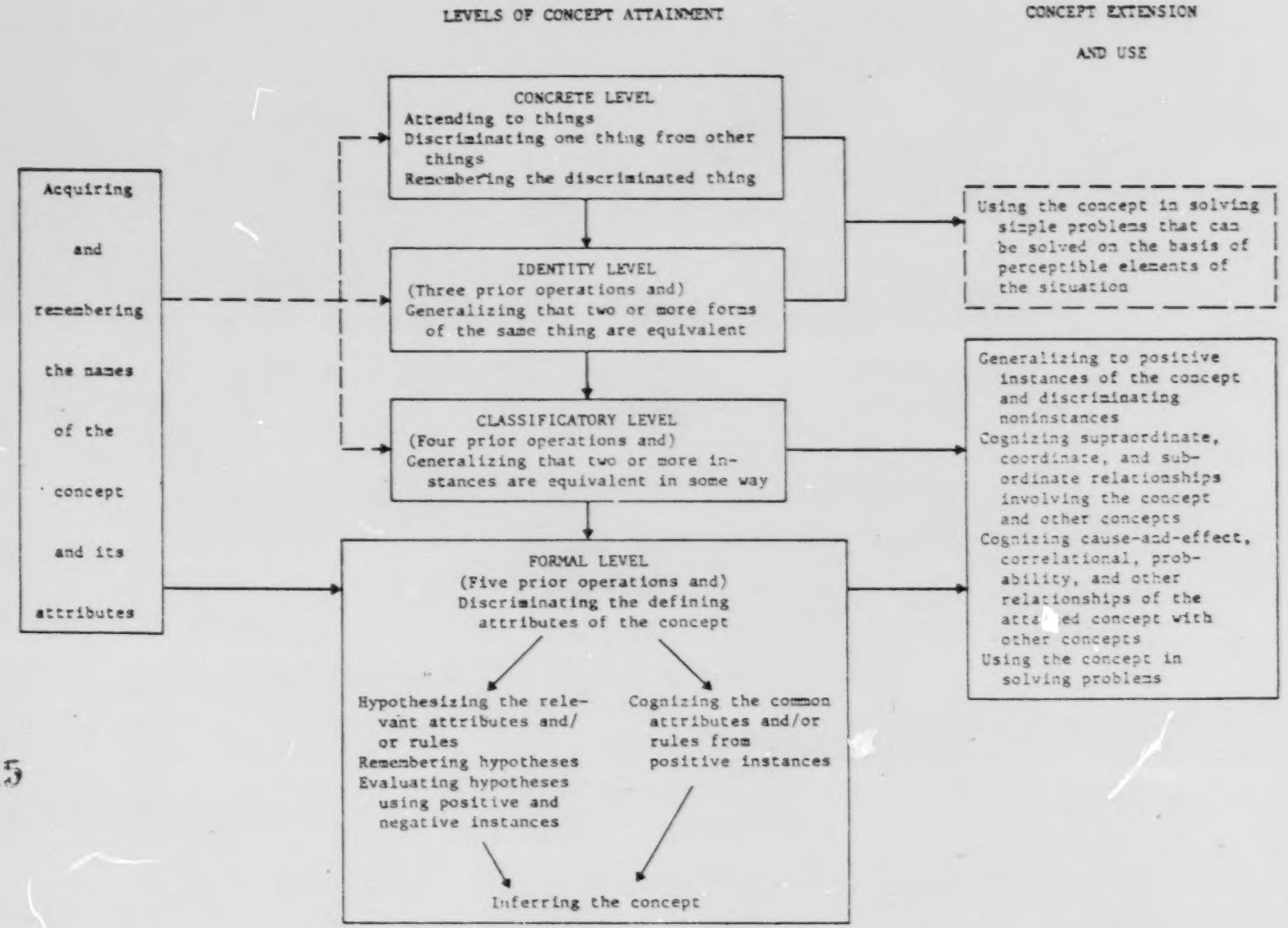
LEVELS OF CONCEPT ATTAINMENT
CONCEPT EXTENSION AND USE
Acquiring and remembering the names of the concept and its attributes
CONCRETE LEVEL
Attending to things
Discriminating one thing from other things
Remembering the discriminated thing
IDENTITY LEVEL
(Three prior operations and)
Generalizing that two or more forms of the same thing are equivalent
CLASSIFICATORY LEVEL
(Four prior operations and)
Generalizing that two or more instances are equivalent in some way
FORMAL LEVEL
(Five prior operations and)
Discriminating the defining attributes of the concept
Hypothesizing the relevant attributes and/or rules
Remembering hypotheses
Evaluating hypotheses using positive and negative instances
Cognizing the common attributes and/or rules from positive instances
Inferring the concept
Using the concept in solving simple problems that can be solved on the basis of perceptible elements of the situation
Generalizing to positive instances of the concept and discriminating noninstances
Cognizing supraordinate, coordinate, and subordinate relationships involving the concept and other concepts
Cognizing cause-and-effect, correlational, probability, and other relationships of the attained concept with other concepts
Using the concept in solving problems

Figure 1. Cognitive operations in concept learning.

generalized to newly encountered instances, related to other concepts, and used in problem-solving situations. Here we are concerned with both transfer of learning and the use of concepts in thinking.

Figure 1 also shows the operations involved in attaining a concept at each level. Attending to and discriminating objects and then remembering what was discriminated are involved in attaining a concept at the concrete level. The same operations are also involved at each subsequent level and are supplemented with the higher-level operations of generalizing, hypothesizing, and evaluating.

Although some of the same operations are posutlated to occur at various levels, what is operated on and remembered changes with the attainment of the successively higher levels. That is, the operations are carried out on more sharply differentiated and abstracted stimulus properties at the four successive levels.

By focusing on the attainment of successively higher levels of the same concept, we are able to clarify the short-term learning conditions at each level and to describe conceptual development over long time intervals. Thus, the model provides a basis for organizing knowledge and carrying out research related to both the external and internal conditions of learning at each of the four levels.

The fourth part of the model shows that acquiring and remembering the name of the concept may come at any of the four levels. The solid line indicates that being able to name the concept and its relevant attributes is essential to attaining the concept at the formal level.

The broken lines indicate that an individual may acquire the name at about the same time he first attains the concept at the lower levels, but that this is not requisite. For example, a young child might attain a concept at all three lower levels but not have acquired the concept name. The younger the children are when they attain the concept, the less likely they are to have the name for it.

At this time, we shall delimit the substantive domain that we are treating. The model in its totality describes the four levels of concept attainment and uses of the same concept rather than each of four kinds of concepts. The four levels apply to the many concepts that are or can be defined in terms of attributes and which have actual perceptible instances or readily constructed representations of instances. We have already cited a few examples of this kind, including all the concepts comprising the plant kingdom and the animal kingdom. However, the operations at each level are intended to be applicable also to different kinds of concepts, some of which, because of their nature, are not attainable at all four levels. We can specify these kinds of concepts and the levels at which they can be attained.

There are some concepts for which there is only one instance, such as the earth's moon and Abraham Lincoln, and some that have many identical instances, for example, inch and pound. Related to Figure 1, such single-instance or identical-instance concepts which have defining attributes can be attained at the concrete, identity, and formal levels, but not at the classificatory level. By our definition of classificatory level,

there must be at least two nonidentical instances that can be placed in the same class. Therefore, some concepts cannot be attained at the classificatory level.

Other concepts are of such low validity that there may not be agreement as to their defining attributes, for example, beauty and morality. Concepts such as these might be learned at the three lower levels but not at the formal level.

Finally, there are concepts with no perceptible instances, such as infinity and atom. These cannot be learned at the three lower levels but might be learned at the formal level.

Returning to the four levels given in Figure 1, we postulate that attaining a concept at the four successively higher levels is the normative pattern for large numbers of individuals under two conditions. First, the concept is of the kind for which there are actual perceptible instances or readily constructed representations; and second, the individual has experiences with the instances or representations starting in early childhood. Furthermore, in order to proceed to the formal level, individuals must acquire labels for the concept and for its attributes. For example, the individual will have successively attained the concrete, identity, and classificatory levels of the concept plant before he describes and treats plant formally in terms of its defining attributes.

Children have direct experiences during preschool years with many things and attain concepts of these things at the first two levels. They also attain many concepts at the beginning classificatory level and

learn the societally accepted names for the concepts and their attributes through formal and informal instruction.

Earlier we indicated that some individuals, because of environmental conditions, may not encounter actual instances of a concept; rather, they experience instances only in verbal form. Thus, these individuals may attain a concept at either the classificatory or the formal level at the outset. It is also noted that the mature person, although capable of attaining a concept at the formal level, may stop at a lower level of attainment because of the way in which the perceptible instances are encountered or other conditions of learning.

OPERATIONS RELATED TO LEVELS OF CONCEPT ATTAINMENT

Having considered the overall features of the model, we may take up the operations in more detail, starting with those pertaining to the concrete level.

Concrete Level

Attainment of a concept at the concrete level is inferred when the individual cognizes an object that he or she has encountered on a prior occasion. We use the tern "operations" as Guilford (1967) does. Guilford has defined the operations of cognition, memory, productive thinking, and evaluation in terms of test performances. He stated that cognition must be related to the products cognized and he formally defined cognition as follows:

> Cognition is awareness, immediate discovery or rediscovery, or recognition of information in various forms: comprehension or understanding. . . . The most general term, awareness, emphasizes having active information at the moment or in the present. . . . The term, recognition, is applied to knowing the same particular on a second encounter. . . . If cognition is practically instantaneous, call it recognition; if it comes with a slight delay, call it "immediate discovery" [pp. 203-204].

The first step in attaining this level is attending to an object and representing it internally. Woodruff (1961) pointed out that:

> All learning begins with some form of personal contact with actual objects, events, or circumstances. . . . The individual gives attention to some object. . . . Through a light wave, or a sound wave, or some form of direct contact with a sensory organ in the body, an impression is picked up and lodged in the mind [p. 66].

Gagné (1970) indicated that as individuals attend to an object, they discriminate it from other objects. Woodruff (1961) called the outcome of these attending and discriminating operations a concrete concept, a mental image of some real object experienced directly by the sense organs. The infant, for example, attends to a large red ball and a white plastic bottle, discriminates each one, maintains a mental image of each, and cognizes each of the objects when experienced later.

The discrimination of objects involves attending to distinctive features that serve to distinguish the objects from one another. Thus, children learn very early to respond to gross differences in such features of objects as size, shape, color, and texture. As children mature, they become capable of making finer discriminations involving these and other features.

Attainment of a concept at the concrete level thus requires attending to the distinctive features of an object and forming a memory image which represents the object as a unique bundle of features. The concept at this level may or may not be associated with the concept label, depending on whether the label has been learned and remembered, and whether it has been associated with the concept.

The preceding analysis of the operations in attaining concepts at the concrete level is sufficiently comprehensive to include motoric experiencing of objects. That is, an object may be manipulated physically and represented enactively, as well as explored visually and represented iconically, to use Bruner's (1964) terminology. The model postulates that attending, discriminating, and remembering are involved in sensorimotor experiencing, to use the terms of Piaget (1970), as well as in the visual perception of objects.

Identity Level

Attainment of a concept at the identity level is inferred when the individual cognizes an object as the same one previously encountered when observed from a different perspective or sensed in a different modality. For example, making the same response to the family poodle when seen from straight ahead, from the side, and from various angles is evidence of the child's having attained the concept of poodle at the identity level. Whereas concept attainment at the concrete level involves only the discrimination of an object from other objects, attainment at the identity level involves both discriminating various forms

of the same object from other objects and also generalizing the forms as equivalent. Generalizing is the new operation postulated to emerge as a result of learning and maturation that makes attainment at the identity level possible.

As noted earlier, there are some valid and powerful concepts, such as the English alphabet, for which there is only one instance but which can be represented in different ways, e.g., aurally and in printed form. These concepts are typically learned at the concrete and identity levels but not at the classificatory level. Therefore, individuals proceed directly from the identity to the formal level with this kind of concept.

Bruner, Goodnow, and Austin (1956) have pointed out that identity responses occur very early in life and that the capability to recognize identity may be innate and merely extended to new events through learning. Vernon (1970) indicates that infants have to learn by experience that objects and events in the environment are permanent even though they may change their appearance from time to time as their distance and orientation changes. Clearly, the capacity to recognize identity, indeed the expectation of the continuity of objects and events in the environment, is well developed in the perception of adults.

Recognition of object identity is central to Piaget's formulations. According to Elkind (1969), Piaget's conception of concept emphasizes the variability that occurs within things--changes in state, form, and appearance which can occur to any entity.

Elkind pointed out further that American psychologists have tended

to ignore this within-instance variability of concepts and have emphasized the discriminative response aspect of concept attainment by which positive instances are cognized and discriminated from noninstances. Elkind summarized the two points of view thus:

> From the discriminative response point of view, the major function of the concept is the recognition or classification of examples. The Piagetian conception, however, assumes that a major function of the concept is the discrimination between the apparent and the real. This discrimination, in turn, can be reduced to the differentiation of between- and within-things types of variability. Here again, a comprehensive conception of a concept must include both functions because, in fact, every concept does serve both purposes [1969, p. 187].

The present model proposes that a concept is attained at the identity level temporally before it is attained at the classificatory level. Stated differently, persons must be able to cognize various forms of the same objects as equivalent before they are able to generalize that two or more different objects belong to the same class.

Classificatory Level

The lowest level of mastery at the classificatory level is inferred when individuals respond to at least two different instances of the same class as equivalent, even though they may not be able to describe the basis for their response. For example, when children treat the family's toy poodle and the neighbor's miniature poodle as poodles, although they may not name the attributes of poodles, they have attained the concept at the classificatory level.

While generalizing that at least two different instances are

equivalent in some way is the lower limit of this level of concept learning, persons are still at the classificatory level of concept learning when they can correctly classify a larger number of instances as examples and nonexamples, but cannot accurately describe the basis for their grouping in terms of the defining attributes. Henley (cited in Deese, 1967), like many other researchers, has observed this phenomenon. Many of her subjects were able to sort cards correctly into examples and nonexamples of the concepts being learned, yet gave totally erroneous definitions of the concepts.

Formal Level

A concept at the formal level is inferred when the individual can give the name of the concept, can discriminate and name its intrinsic or societally accepted defining attributes, can accurately designate instances as belonging or not belonging to the set, and can state the basis for their inclusion or exclusion in terms of the defining attributes. For example, maturing children demonstrate a concept of dog at the formal level if, when shown dogs, foxes, and wolves of various sizes and colors, they properly designate the dogs as such, call them "dogs," and name the attributes that differentiate the dogs from the foxes and wolves. The distinctive aspect of this level of concept mastery is the learner's ability to specify and name the defining attributes and to differentiate among newly encountered instances and noninstances on the basis of the presence or absence of the defining attributes.

As noted in Figure 1, the labels for the concept and the defining attributes may be learned at any of the three lower levels, but are not essential at those levels. Similarly, the discrimination of the defining attributes may occur prior to the formal level, but this is not essential. Thus, discrimination of things on their global and diffuse stimulus properties which is essential at the concrete level changes to discrimination of more specific and abstract properties at the identity and classificatory levels. However, at the formal level the individual must be able to discriminate and label all the defining attributes of the concept.

The operations involved in the learning of concepts at the formal level are also shown in Figure 1. The first operation given at the formal level is that of discriminating the attributes. As already noted, for some concepts with obvious attributes such as color and form, the discriminations may have occurred at earlier levels. However, making the discriminations and having the labels for the attributes are both essential at the formal level. This is true whether the individual infers the concept by hypothesizing and evaluating relevant attributes or cognizing the attributes common to positive instances, as shown in Figure 1.

Individuals differ in their ability to analyze stimulus configurations into abstract dimensions or attributes. There is evidence (Gibson, 1969) that this ability develops with age. Retarded children may have difficulty with simple concept learning tasks because of the

difficulty in learning to select out and attend to specific dimensions (Zeaman & House, 1963). Even among children of adequate intelligence, there are those who characteristically analyze the stimulus field and apply labels to attributes while others tend to categorize on the basis of a relatively undifferentiated stimulus (Kagan, Moss, & Sigel, 1963).

Orienting instructions may be given to make explicit the attributes of the stimuli (Klausmeier & Meinke, 1968). These instructions facilitate the learning of concepts at the formal level by assuring that the learner knows all of the attributes that may be relevant to the concept.

Having discriminated and named the attributes, an individual may infer the formal level of a concept inductively in either of the two ways shown in Figure 1. One way involves formulating and evaluating hypotheses and the other involves cognizing the common attributes in positive instances. Which strategy a learner uses depends on the instructions he has been given, his age, and the kind of concept instances he experiences.

Levine (1963) defined a hypothesis as the subject's prediction of the correct basis for responding. In the hypothesis-testing approach, learners guess a possible defining attribute or combination of attributes. They then compare this guess with verified examples and nonexamples of the concept to see whether it is compatible with them. If the guess is not compatible, they make another guess and evaluate it against

further examples and nonexamples. Eventually, they combine the information they have obtained from testing their hypotheses so as to infer all the defining attributes and thereby the concept.

Essential to the hypothesis-testing approach are the operations of remembering and evaluating hypotheses. There is support (Levine, 1963; Williams, 1971) for the idea that the subject formulates and remembers a population of hypotheses, remembers the hypotheses that were rejected, and also remembers the last one accepted as correct. In connection with evaluating hypotheses, Bruner et al. (1956) indicated that individuals determine whether or not their hypothesized concepts are valid by recourse to an ultimate criterion, test by consistency, test by consensus, or test by affective congruence. Inherent in all four procedures is establishing a criterion for judging the correctness of a hypothesis. In the present model, the validity of an individual's concept may be assessed in terms of how nearly it corresponds to expert agreement concerning the concept. Our experiments have shown that instructions to subjects which include a decision rule for evaluating hypotheses facilitate concept attainment.

The operations involved in the hypothesis-testing approach to inferring concepts appear to characterize individuals who cognize the information available to them in laboratory and classroom settings from both positive instances (examples) and negative instances (nonexamples). These individuals apparently reason like this: Instance 1 has land surrounded by water. It is a member of the class. Instance 2

has land but it is not surrounded by water. It is not a member of the class. Therefore, lands surrounded by water belong to the class and lands not surrounded by water do not. Surrounded by water is a defining attribute of the concept. This individual has attained a partial but accurate definition of the concept based on experiences with only one positive and one negative instance.

A second inductive way of inferring the concept is by noting the commonalities in examples of the concept. The commonality approach is used more often than the hypothesizing approach by children, apparently because they are either incapable of getting information from nonexamples or because they cannot carry out the hypothesizing and evaluating operations (Tagatz, 1967). The commonality strategy is the only one possible when only positive instances of the concept are available.

Our model is considered appropriate for learning concepts at the formal level by a didactic method of information presentation as well as an inductive one. That is, concepts may also be learned at the formal level deductively.[1] Many upper elementary, high school, and college students are given the names of concepts and their attributes, verbal definitions, verbal examples, and verbal nonexamples but not actual instances of the concepts. To learn the concept initially they must assimilate this information, remember it, and be able to use it in evaluating examples and nonexamples of the concept as shown in Figure 2. When learners have attained a concept initially through this kind of didactic instruction, they are able to use the concept

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[1] In explaining the model earlier, Klausmeier, Ghatala, and Frayer (1974) subsumed the deductive operations under cognizing the common attributes.

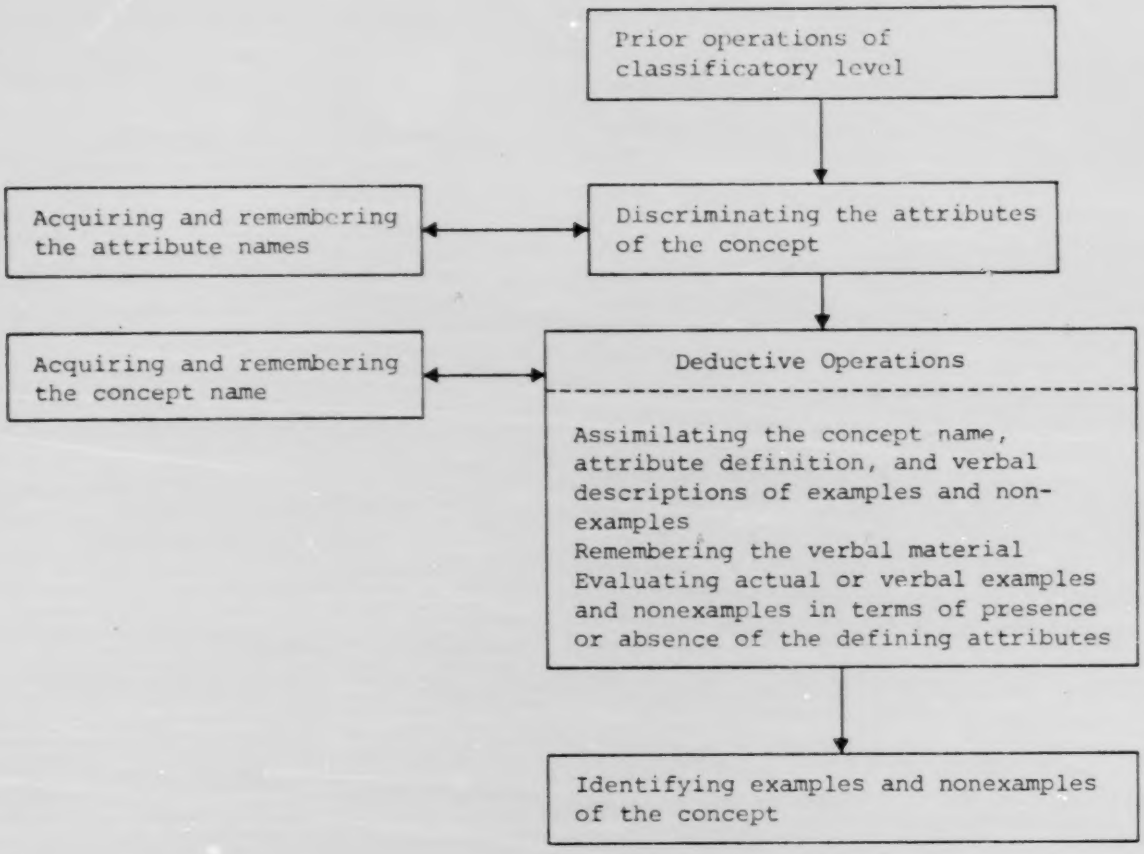

Prior operations of classificatory level
Acquiring and remembering the attribute names
Discriminating the attributes of the concept
Acquiring and remembering the concept name
Deductive Operations
Assimilating the concept name, attribute definition, and verbal descriptions of examples and non-examples
Remembering the verbal material
Evaluating actual or verbal examples and nonexamples in terms of presence or absence of the defining attributes
Identifying examples and nonexamples of the concept

Fig. 2. Cognitive operations and deductive strategies of concept attainment at the formal level.

to identify new examples and nonexamples with which they have had no prior experience. The basic operations entailed in this identification of newly encountered instances are hypothesizing whether the instance does or does not belong to the concept and evaluating the hypothesis in terms of the defining attributes that were given in the definition. Prerequisite to these two operations are discriminating the attributes of the concept and knowing their labels. All of these are listed in Figure 1 as part of the inductive strategy. Thus, when didactic instruction is used, the learner must hypothesize and evaluate regarding examples and nonexamples in order to use the newly learned concepts.

ACQUIRING APPROPRIATE LABELS

The importance of language in concept learning is widely acknowledged by American (Bruner, 1964) and Russian (Vygotsky, 1962) psychologists. Having the labels of concepts enables individuals to think in symbols rather than in images and to attain other concepts through language experiences in the absence of perceptible instances. Carroll (1964), as noted earlier, has outlined the close relationships among concepts, meanings, and words. However, the purpose here is not to deal with the relationships between language and concept learning, but to show at what points labels may be learned and associated with the various levels of concepts.

Figure 1 indicates that a concept label may be associated with an instance of the concept at any of the four levels--concrete, identity, classificatory, or formal. For example, Billy might manifest a sequence

like this: Billy first encounters a dog. Billy's mother points to the dog and says "dog." Billy then says "dog," and associates the name with his concrete concept of the dog. Next, Billy develops the concept of the same dog at the identity level through experiencing it in different locations and situations. His mother repeats the name at various times in the presence of the dog; Billy says the word repeatedly. The word "dog" now comes to represent Billy's concept of the dog at the identity level. Subsequently, Billy encounters other dogs and observes that they, too, are called "dogs." He generalizes the different dogs as equivalent in some way and associates the name "dog" with whatever similarities he has noted. The word thus comes to represent his class of things called "dogs." At the formal level, with greater maturity, Billy discriminates and learns the societally accepted attributes of the class of things called "dogs" and also learns the names of the attributes. Now Billy's concept of dog approaches or becomes identical to the societally accepted definition of the word "dog." As Carroll (1964) pointed out, the concepts held by individuals and the meanings of the words representing the concepts are the same for mature individuals who share similar cultural experiences and the same language.

In connection with language and concept attainment, we recognize that deaf individuals and others who lack normal speech development may attain concepts at the formal level. By our definition, the individual must know the defining attributes of the concept and must be able

to communicate this knowledge. Verbalizing is normally used in this kind of communication. Other types of symbolic communication, for example, sign language, may also be employed. Speech, per se, is not necessary for the attainment of concepts, but some means for symbolizing and communicating the concept in the absence of examples is necessary at the formal level.

CONCEPT EXTENSION AND UTILIZATION

The individual who has formed a concept may extend and use it as shown in Figure 1. As noted earlier, a concept attained only to the concrete or identity level may be used in solving simple perceptually-based problems. Concepts learned at the classificatory and formal levels can be used in generalizing to new instances, cognizing supraordinate-subordinate relationships, cognizing cause-and-effect and other relations among concepts, and in solving problems.

Ausubel (1963) and Gagné (1966, 1970) have theorized concerning the use and extension of attained concepts; however, very little empirical research has been done. In this regard Ausubel (1966) formulated the constructs of cognitive structure, advance organizer, correlative subsumption, and derivative subsumption to show how previously attained and newly encountered concepts are related, while Gagné has indicated that attained concepts are prerequisite to the learning of rules.

Generalizing to New Instances and Discriminating Noninstances

The attainment of concepts at the classificatory and formal levels reduces the need for additional learning and relearning, primarily

because the individual is able to generalize to new instances of a concept and to discriminate noninstances. Having a concept also provides individuals with expectations which help them deal effectively with new instances of it. Once persons identify a plant as poison ivy, they treat it gingerly. One test of concept attainment in our experiments is the individual's ability to properly categorize instances not previously encountered as instances or noninstances of the particular concept. We find that both school children and collegeage students generalize to new instances readily. Furthermore, the use of instances and non-instances in instructional materials to teach concepts can be manipulated so that errors of overgeneralization and undergeneralization can be reduced (Feldman, 1972; Swanson, 1972).

Not only does having a concept enable learners to identify new instances and act appropriately toward them, but direct and verbal experiences with the new instances possibly increase the validity and power of the concept for the individual. For example, the Canadian visiting Kenya during January, when it is summer there, may attain more valid and powerful concepts of flower and plant. Similarly, by being told that a whale is a mammal, an individual comes to realize that mammals can live in the water as well as on land. Hence, the individual's concept of mammal has greater validity.

Cognizing Supraordinate-Subordinate Relationships

Besides generalizing to new instances, individuals can also use their concepts attained at the formal level, and possibly at the

classificatory level, in cognizing coordinate, supraordinate, and subordinate relationships among classes of things. The lowest level of cognizing these relationships is inferred when persons, according to verbal instructions, put instances of concepts in their proper groups. For example, upon request persons put all instances of red and blue equilateral triangles and of right triangles in a grouping of triangles, and all instances of triangles and of rectangles in a grouping of polygons. Furthermore, they justify each group formed on the basis of the defining attributes of the group. For example, they state that equilateral triangles include all the triangles that have three equal sides, triangles include all the polygons that have three sides, and polygons include all the closed, planar figures that have three or more sides. More precise terminology might be required such as "an equilateral triangle is a simple, plane, closed figure with three sides of equal length."

Possible higher levels of attaining the supraordinate-coordinate-subordinate relationships include what Kofsky (1966) designated as the "whole is the sum of the parts" and "some but not all." Again, merely being able to group a few instances properly according to verbal instructions is not a sufficient test of cognizing the sets of relationships; an adequate justification for the actions is required. According to Kofsky (1966), knowledge concerning supraordinate-subordinate relationships increases with age.

The understanding of supraordinate-subordinate relationships

increases the validity and usability of the individual's concepts. For example, knowing the attributes of acid and also knowing that vinegar is an acid leads to the inference that vinegar has the attributes of all acids, as well as the attributes peculiar to vinegar. Thus all of the things known about acids--for example, how they react with bases--are true for vinegar also. In this way, learning that acid is a concept supraordinate to vinegar increases the validity and usability of the concept of vinegar for the individual.

Cognizing Other Relationships

There are other statements of relations between or among concepts that are different from relations among supraordinate and subordinate concepts. These additional statements, often termed principles, have been classified by Klausmeier, Ghatala, and Frayer (1974) according to the type of relation that is stated:

1. Cause and effect relationships are statements that may also be expressed in terms of an "if-then" relationship. For example, "tuberculosis is caused by the organism Myobacterium tuberculosis"; "contact with a hot stove produces a blister."

2. Probability statements are principles that express numerically the likelihood of an event's occurrence. For example, "the probability of giving birth to a boy during any given pregnancy is .52"; "provided the coin is fair, the probability of getting a head on only one toss of the coin is .50."

3. Correlational statements describe a relation, often expressed numerically, between two or more objects or events. For example, "If height and weight are measured for a large number of people, the resulting correlation between the two measures is around .50"; "the incidence of lung cancer in women is increasing and the number of women smoking cigarettes is increasing."

4. Axiomatic statements, the most inclusive type of principle, are universally accepted, self-evident truths. Five subclasses have been identified by Bernard (1975): (a) fundamentals, or principles essential to a science, religion, philosophy, or art; (b) laws, or statements of relationship of phenomena that always hold true; (c) rules, or principles in various subject matter domains that prescribe usage, procedure, or conduct; and (d) theorems and (e) axioms, both of which are usually mathematical statements of a relation to be proved or already proved.

Marx (1970) has referred to cause-and-effect, probability, and correlational statements as laws. Gagné (1970) has called these same types of statements principles or rules. In discussing rule learning, Gagné proposed two schemes for classifying rules. The first, based on rule content, divides rules according to those in which the rule relates concepts and designates ideas in contrast to those in which the content functions to guide the individual's response in a specific situation. The second scheme of classification for rules is based

on rule structure--either simple or complex. The most simple rules consist of two concepts, arranged in a chain, in the form "if A, then B." Complex rules consist of a larger number of concepts which are often abstract and require subtle discriminations.

Although the various types of statements that express relations among concepts have been classified in slightly different ways by different experts, it is agreed that understanding these statements is critical to thinking and reasoning. Understanding statements of cause and effect or probability, for example, enables the individual to predict consequences from known conditions and to explain newly encountered phenomena. Bruner et al. (1956) have pointed out that understanding lawful relationships between or among concepts permits classes of things, rather than isolated, individual things, to be related. Gagné (1970) has suggested that the structurally simple rule "round things roll" is the kind of rule young children learn very early because it consists of concrete concepts having clearly perceptible instances. Once learned, this rule enables the child to predict what will happen to all spherical objects under certain conditions. Or, consider the more complex relationship: "When two substances at different temperatures come into contact, the temperatures of the substances tend to equalize." This relationship permits us to infer what will happen is such diverse situations as putting ice cubes in warm soda pop or being lost in a snowstorm.

In all cases, of course, being able to understand and use a lawful

relationship is contingent upon knowing the concepts embedded in the statement. Only then can the rule or axiom or principle be understood and applied to appropriate phenomena.

Using Concepts in Problem-Solving Situations

Problem-solving ability is treated by Klausmeier (in press) as one of the most critical of all outcomes of education; a person who is capable of solving problems can learn independently. A considerable amount of instruction is directed toward teaching students problem-solving skills, and students acquire considerable knowledge through problem solving. Concept learning itself may be regarded as a special case of problem solving.

A situation requiring problem solving is encountered when an individual must respond but does not have immediately available the specific information, concepts, principles, or methods to arrive at a solution. To solve any problem the individual must think adaptively; more specifically, the individual must selectively recall important concepts, principles, and methods needed to solve the problem. Thus, not only may one or more concepts be instrumental in the solution of many kinds of problems, but the more experience an individual has with a given concept, the greater the probability of solving successfully a problem involving that concept.

Much of the organized knowledge concerning the nature of problem solving has been summarized in diverse theories, descriptions of the steps in problem solving, and descriptions of the internal and external

conditions of learning. Although varying slightly in their emphases, these theories and descriptions all attest to the importance of problem solving in complex learning and thinking. In turn, theorists have also focused on the role played by concepts in problem solving. For example, Woodruff (1967) has discussed the role of concepts in higher-level mental activities, including problem solving. In accord with his cumulative model of learning, Gagné (1970) has viewed concepts as prerequisite to the learning of rules, and rules as prerequisite to the solving of problems. Gagné has also indicated that one way in which concepts are called into play in solving problems is by the application of principles to the problem-solving situation. For example, principles underlying the concepts of pressure, volume, gravity, and distance can be utilized to determine the height of a mountain by using a barometer.

ADDITIONAL FEATURES OF THE CLD MODEL

The CLD model is more heavily oriented toward learning than toward development in that it implies that all the concepts held by any individual are learned; they do not emerge simply with maturation. In this context it is similar to four theories of concept learning generated by American experimental psychologists and reviewed by Bourne, Ekstrand, and Dominowski (1971): theory of associations (Bourne & Restle, 1959); theory of hypotheses (Levine, 1966; Trabasso & Bower, 1968); theory of mediation (Osgood, 1953); and theory of information processing

(Hunt, 1962). Also, in agreement with these theories, the model specifies that the attainment of concepts is potentially explainable in terms of principles of learning. Despite some differences in terminology, the CLD model, like Hunt's, represents an information-processing approach to learning. The CLD model differs from the four theories just mentioned in that it describes different levels in the attainment of the same concept and specifies the operations essential to attaining concepts at the successively higher levels. While some of the operations are postulated to be common to more than one level, these operations at the successively higher levels are carried out on more highly differentiated and abstracted properties of actual concept instances or on verbal descriptions of instances and attributes.

The CLD model is similar to Gagné's (1970) cumulative learning model in that both provide a framework for studying the interral and external conditions of learning. It also differs in two regards. Whereas Gagné describes seven forms of learning, ranging from the simplest learning through rule learning and problem solving, in the CLD model only one form of learning, concept learning, is analyzed according to its several constituent cognitive behavirors at each of four levels. Gagné also postulates a linear vertical learning hierarchy extending from signal learning through problem solving. The CLD model, as shown in Figure 1, indicates that a concept when learned at the classificatory or the formal level may be used in cognizing supraordinate-subordinate relations among the concept and other attained

concepts, in understanding relations among concepts such as those incorporated in principles and laws, and in problem solving. Thus, the CLD model departs from the straight linear learning hierarchy postulated by Gagné.

Possibly different from the preceding learning theories and more in agreement with Piaget (1970), the CLD model presumes that the new operations at each successive level involve qualitative changes in operating on instances and attributes of concepts, not merely additions to or modifications of prior operations. Further, the operations that continue from one level to the next are carried out on more highly differentiated and abstracted concept attributes. While the model does not postulate a stage concept associated with age levels as does Piaget, qualitative differences in thinking of the kinds pointed to by Bruner, Olver, Greenfield et al. (1966) and Kagan (1966) are recognized. Also, Bruner's (1964) conceptualization of enactive, iconic, and symbolic representation is accepted as a satisfactory global explanation of how experiences are represented and stored.

The roles of language and directed learning experiences are recognized as being of central importance in attaining concepts at the classificatory and formal levels. The cross-cultural studies of Bruner et al. (1966) support the directed-experiences point of view (cf. Goodnow, 1969). Also, Bruner's (1964) intermediate position that specifies how language facilitates thinking, rather than being essential to thinking (Luria, 1961) or being dependent on thought (Inhelder

& Piaget, 1964), appears valid for the present model. Accepting directed experience as critical in concept attainment de-emphasizes a maturational readiness viewpoint, such as that expressed by Gesell (1928, 1945). While it is accepted that certain cognitive operations emerge with educational experience, this conception does not espouse a behaviorist-environmentalist point of view regarding learning to the extent that either Gagné (1970) or Staats (1971) does.

II

PURPOSES AND METHODS OF THE STUDY

The purpose of the longitudinal intervention study is to determine whether students can be taught concepts and their uses more effectively. Knowledge that has accrued during the past decade concerning the internal conditions of learning and the external conditions of learning will be incorporated in this longitudinal study (see Hooper & Klausmeier, 1973, Pps. 49-66); thus, this study constitutes the final step in the application of knowledge about conceptual learning and development to the improvement of instruction in the school setting.

OVERVIEW OF THE STUDY

Table 1 provides a timetable for carrying out the intervention study and preparing the related reports. During 1973-1974 two controlled experiments were run to determine the extent to which children's level of concept attainment could be increased from the classificatory level to the formal level as these levels are defined in the model of conceptual learning and development (Klausmeier, Ghatala, & Frayer, 1974). In one experiment (McMurray, Bernard, & Klausmeier, 1975) two experimental lessons to teach the concept equilateral triangle were developed and taught to fourth-grade children. In this experiment, a variation of the Solomon

TABLE 1

TIMETABLE FOR INTERVENTION STUDY AND REPORTS

	1973-74	1974-75	1975-76	1976-77	1977-78	1978
Conduct controlled experiments	X	X	X	X		
Develop evaluation instruments and instructional materials		X	X	X		
Plan intervention procedures with school staffs		X	X	X		
Conduct trial intervention experiment		X				
Implement intervention process and gather data			X	X	X	
Develop related monograph on learning and teaching concepts		X	X	X	X	
Develop three filmstrips				X	X	X
Deliver reports of research carried out prior year			X	X	X	X

Four-Group design was employed to determine the effects of a pretest as well as the lessons. Performance of the participating 118 fourth-grade children indicated that experimental groups receiving the lessons performed better than did the control groups. A two month follow-up assessment showed that the experimental groups receiving the lessons lost very little in performance and that the two control groups had increased their level of attainment only slightly. The pretest was found not to have a significant effect on performance. The specific results were: (1) 94 and 93 percent of the two experimental groups receiving the lesson attained the classificatory level, whereas 73 and 64 percent of two control groups did, and (2) 60 and 64 percent of the two experimental groups attained the formal level, whereas only 7 and 11 percent of the two control groups did. The performances of the fourth-grade experimental children is especially significant inasmuch as the performances of a comparable group of sixth-grade students attaining the classificatory level and the formal level of the same concept, equilateral triangle, were as follows: 90 percent attained the classificatory level and 46 percent attained the formal level (Klausmeier, Sipple, & Allen, 1974b).

In another of the controlled experiments conducted during 1973-74, it was found that the materials designed to assess attainment of the concept tree were too easy for fifth-grade children (Klausmeier, Schilling, & Feldman, 1976). The study was therefore replicated with third-grade children in 1974-75. The results of the 1974-75 study were similar to those of the McMurray, Bernard, and Klausmeier study (1975) involving equilateral triangle.

In both of the controlled studies carried out during 1973-74, the experimental lessons utilized methods which have previously been found to facilitate concept learning: presenting a definition of the concept together with rational sets of examples and nonexamples, emphasizing the defining attributes of the concept, teaching a strategy and providing immediate feedback. These same variables were incorporated in lessons developed for the intervention study.

Controlled experiments projected through 1976-77 (see Table 1) will continue to clarify instructional variables. The results of these experiments will be incorporated in the intervention procedures. In the 1974-75 school year, accomplishments were as follows: (1) the evaluation instruments and instructional materials were developed, (2) the intervention procedures were planned with the school staffs, (3) a trial intervention experiment was conducted, and (4) a monograph on the learning and teaching of concepts was begun. The purpose of this monograph is to bring together the basic knowledge regarding the learning and teaching of concepts as it is generated through this longitudinal intervention study.

In 1975-76, 1976-77, and 1977-78 the intervention process will be implemented. Also the related monograph on learning and teaching concepts will be refined. An annual report will be prepared each year with the final monograph to be completed during the calendar year 1978.

METHOD

The more specific plan for carrying out the intervention has two major elements. First, lessons developed by the project staff will be

used by the teachers of the experimental schools. These lessons were designed to teach the "process" concepts of science that are incorporated in the curriculum Science: A Process Approach (SAPA). The concepts to be taught, therefore, deal with processes of science as defined in this published curriculum, e.g., observing, classifying, predicting, inferring, controlling variables. Second, teachers will change their mode of instruction from one of keeping classroom groups intact while proceeding through the curriculum, to implementing instructional programming for the individual students. This instructional programming procedure is a modification of the Instructional Programming Model in IGE (Klausmeier, Quilling, Sorenson, Way, & Glasrud, 1971).

Children in the fourth grade (corresponding to level five, or the fifth year of schooling) and in the fifth grade (level six, or the sixth year of schooling) will participate in the study during the 1975-76 school year. Interventions will continue with the level 5 children through the 1976-77 and 1977-78 school years to ascertain the cumulative effects of the interventions.

Intervention Procedures

The general plan of the data collection and the intervention is as follows:

1. In both control and experimental schools, teach the usual SAPA lessons during each year in the same sequence. Each teacher will keep a descriptive log concerning the amount of time given to each lesson and the kinds of materials and activities used.

2. At the beginning of each semester in both control and experimental schools, administer the content-specific tests covering the SAPA lessons that will be taught during the semester (pretest). Administer the same tests at the end of each semester (posttest).

3. In the experimental schools at the beginning of each process block (a set of SAPA lessons dealing with the same process) provide instruction using a project prepared process-concept lesson. The process-concept lessons will not be used in the control schools.

4. In the experimental schools, plan and teach the SAPA lessons according to the sequence agreed upon by the project and school staffs. Organize instruction for small groups of students based on the pretest results. In the control schools continue to teach the children as the staffs normally organize instruction.

5. In the experimental schools, provide for differences in achievement on each set of SAPA lessons and process-concept lessons; e.g., enrichment for mastery group, reteach for near mastery group. The control schools will not carry out these activities.

The intervention procedures as described above were planned cooperatively with the staffs of the two experimental schools during the 1974-75 school year. The schedule of activites and use of data gathering instruments was also planned with the staffs of the control schools.

Description of Participating Schools

The selection of the two experimental and the two control schools was carried out in conjunction with the school system's administrators.

The schools were selected in accord with the representative socioeconomic, ethnic, and general demographic classifications found in the city of Janesville, Wisconsin. Two nongraded schools were selected, one (School A) assigned to the experimental and one (School B) to the control condition; and two schools with graded classrooms were selected, one (School C) assigned to the experimental and one (School D) to the control condition.

In each of the four schools there are either one or two unit leaders and from one to four teachers of science at each level. Approximately 85 children are enrolled in each level at each school. Fifty to 80 percent of the populations of the four schools fall in the middle and higher-than-middle socioeconomic status. Blue collar, business, and professional occupational categories are represented by the parents of the children attending the schools.

Data Collection and Analysis

At the beginning of each semester, teachers in each of the experimental and control schools will administer those content-specific tests that correspond to the SAPA lessons being taught during that semester. At the end of the semester, after SAPA instruction, the tests will be re-administered. The lesson and testing sequence has been agreed upon by the teachers and will be the same for all schools.

A short Attitude Towards Science measure will be administered to all experimental and control children at the beginning of each school year prior to any testing or instruction, again at the end of the first semester,

and finally in the spring after all testing and instruction are completed (see Appendix A).

In addition to the above testing, both the experimental schools receiving the process-concept lessons and the control schools not receiving the lessons will be given process-concept assessments.

In order to obtain explicit information concerning the implementation of the experimental materials and procedures, a teacher's log will be completed by all teachers for each SAPA lesson taught. The experimental school teachers will record: (1) the number of days and amount of time required to teach each SAPA lesson; (2) the number of students in each of three instructional groups (high-achievers, medium-achievers, and low-achievers); (3) how instruction was differentiated for each group; (4) the SAPA materials used; and (5) the supplementary materials used. The control school teachers will record only (1), (4), and (5) from above (teacher logs are presented in Appendix B).

Statistical analyses of the content-specific test scores will involve the use of the analysis of covariance technique. The main effect to be tested will be the instructional materials and procedures of the experimental versus the control schools. The covariates to be used will be content-specific pretest scores. The dependent variable will be total number of items correct on each content-specific test. A second analysis may be performed using the total number of items correct on all of the content-specific tests within a process block.

Statistical analysis of the process-concept assessment data will also involve the analysis of covariance technique. The main effect to be tested will be the instructional materials and procedures of the experimental versus the control schools. The covariate used will be Vocabulary and Comprehension scores on the Gates-MacGinitie Reading Test. Two dependent variables will be used: total number of items correct on the classificatory subtest and total number of items correct on the formal subtest.

III

DEVELOPMENT OF CONTENT-SPECIFIC TESTS

In this chapter the purpose and construction of the content-specific tests are described. The technical characteristics of the first version tests are also reported.

PURPOSE OF THE CONTENT-SPECIFIC TESTS

The purpose of the tests is to measure knowledge of SAPA content. At the beginning of each semester, the instruments will be given as a pretest in both the experimental and the control schools. The same tests are also used as posttests at the end of the semester of instruction. In addition, the tests will be used throughout each semester in the experimental schools to group students for differentiated instruction.

CONSTRUCTION OF CONTENT-SPECIFIC TESTS FOR LEVELS FIVE AND SIX

During the summer of 1974, project personnel drafted preliminary versions of content-specific tests: 17 tests to correspond to the 17 SAPA lessons taught at each level. Items in each test measured knowledge of (1) SAPA lesson content or (2) key vocabulary associated with the SAPA lesson. The prototype for the content items was those parts of the SAPA lesson called "appraisal" and "competency measure." These parts are intended to be individually administered to

each child following the teaching of a SAPA lesson. The prototype for the vocabulary items was the "key words" section in the teacher's guide prepared by SAPA for each lesson. In addition, words which teachers judged important were also included in the vocabulary test.

For the purpose of this study all tests were designed as paper-and-pencil tests to be group administered. Also, the items and instructions were to be read aloud to the students. Occasionally, it was not possible to construct a paper-and-pencil item corresponding to a manipulative or psychomotor skill being tested in the SAPA competency measure. In such cases, a paper-and-pencil item was written to approximate the intent of the original SAPA item. At least two multiple-choice items per SAPA objective were written. After all content and vocabulary items had been developed, they were reviewed for clarity and format and revised by test construction specialists. In addition, the tests were reviewed by a professor of science education, a fourth grade teacher, a science consultant, and a reading consultant from the participating school district. A tryout of each test was conducted following the reviews using groups of children from level five and level six. The children were chosen to represent low, medium, and high levels of scholastic achievement. Summary statistics for the level five and level six tests obtained from this tryout are presented in Appendix C. A representative level five test (revised) is presented in Appendix D.

IV

DEVELOPMENT OF PROCESS-CONCEPT ANALYSES

Before preparing lessons the concepts to be taught in the lessons must be analyzed. There are eight basic process-concepts in Science: A Process Approach and five integrative processes. The specific procedures for conducting the analysis for each of the concepts are described in this chapter. The analysis of the concept observing scientifically is used to illustrate each step in the analysis.

Subject matter taught to children, kindergarten through high school, should be selected in the context of the structure of knowledge of the particular discipline or disciplines. This implies that the person conducting a concept analysis should know where the particular concept fits into a taxonomy or hierarchy, how it is defined by experts in the discipline, its use in principles, and its use in solving various kinds of problems.

Conducting a concept analysis includes (1) outlining the taxonomy or the hierarchy of which the target concept is a part, (2) defining the concept in terms of its defining attributes, (3) specifying the defining attributes and some of the variable attributes of the concept, (4) indicating illustrative examples and nonexamples of the concept, (5) identifying illustrative principles in which the concept is incorporated,

(6) formulating illustrative problem-solving exercises involving use of the concept, and (7) developing a list of the key vocabulary associated with the concept and its defining attributes. Procedures for carrying out steps (2), (3), and (4) are based on the pioneering work of Markle and Tiemann (1969), while the other steps are related directly to the model of conceptual learning and development developed by Klausmeier, Ghatala, and Frayer (1974).

Experience in developing concept analyses indicates that they have greatest utility in subsequently preparing instructional materials for any desired level of schooling when the analysis is directed toward the formal level of attaining the concept, and when the complete analysis is expressed in terminology appropriate for senior high school students rather than for young children. However, what is subsequently included in a particular set of instructional materials or methods must be related to the level of concept attainment to be taught and to the level of vocabulary and other characteristics of the target student population. A description of the procedures for conducting a concept analysis follows, using as examples of each procedure information pertaining to the concept observing scientifically. Each procedure is described in some detail because a concept analysis provides much of the information needed to develop instructional materials to teach the concept.

OUTLINING A TAXONOMY OR HIERARCHY

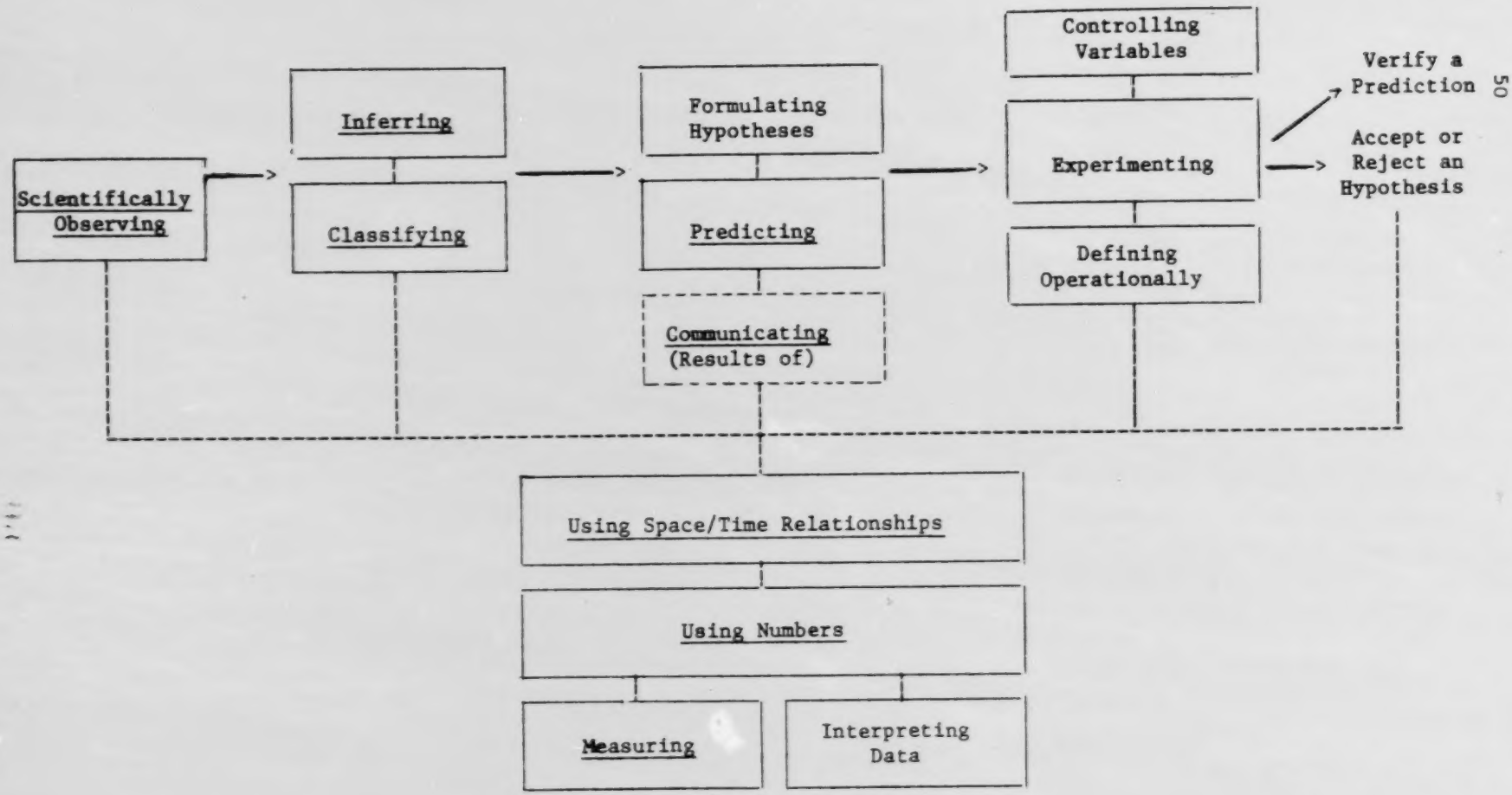
A starting point for analysis of a concept is outlining the taxonomy or the hierarchy of which the concept is a part. A taxonomy involves inclusive-exclusive relationships among classes of things

whereas a hierarchy implies relationships among things ordered by some principle, such as of importance, priority, and dependency. A learning hierarchy results from an analysis of a learning task. Three assumptions underlying this kind of analysis, and the concept of learning hierarchy, are that learning tasks can be analyzed into skills, all persons must learn the same prerequisite skills in order to perform a particular task, and the same sequence of instruction will facilitate their learning.

The hierarchical organization as shown in Figure 3 for the process concept observing scientifically results from an analysis of the inquiry skills in science that students should learn to perform during their elementary school years, not from an analysis of the skills essential to performing and reporting an experiment. However, the arrows do indicate dependency relationships of a non-inclusive type among concepts. For example, observing events is essential and prerequisite to drawing inferences about the events and also for classifying the events observed. In this kind of hierarchical organization of concepts, there may or may not be coordinate concepts at certain levels of the hierarchy.

In Figure 3 the solid lines without arrows show a nondependency but not necessarily a coordinate relationship among the concepts. The defining attributes of the concepts and the inclusive-exclusive relationships in a hierarchical organization of concepts are very different from those in a taxonomy.

Bruner (1960) made a useful distinction between the structure of knowledge in a discipline and a structure of knowledge that is learnable



58 Figure 3 Hierarchy involving observing scientifically. (Klausmeier, Swanson, & Sipple, 1976)

The process concepts in this figure are drawn from Science: A Process Approach (AAAS Comm. on Science Ed., 1967) however, the figure itself is not. The relationships are presumed to be compatible with the SAPA curricular program. The basic processes as specified by SAPA are underlined while integrated processes are not. Arrows indicate prerequisite relationships among processes, solid lines connect coordinate or closely-related processes; and dotted lines indicate non-hierarchical linking relationships involving communicating.

by students. However, the latter cannot be derived without the former. Without knowledge of both kinds of structures, one cannot proceed intelligently in the analysis of concepts. At present much of the substance of school subject matters that could be organized into either taxonomies or hierarchies is not. In the absence of this kind of information, taxonomies and hierarchies are developed by using available printed materials and also by securing assistance from persons with expertise in the particular subject matter. The hierarchy presented in this section was formulated in this manner.

DEFINING THE CONCEPT

Whether or not students will be taught a definition of the word representing the concept, the person conducting an analysis must know or arrive at a societally accepted definition. Further, so that examples and nonexamples may be identified for use in teaching and testing, the meaning of the word should be stated in terms of the defining attributes of the concept represented by the word.

Observing scientifically: Using one or more of the senses in critically examining objects or events and precisely recording data about those objects or events.

The reader will recognize that observing scientifically can be treated as a process concept that can be understood, as a process or skill that can be performed, or both. The authors treat it as both and presume that students' understanding it as a concept facilitates their learning to carry it out as a process.

In connection with generating word definitions we recognize that the same word may represent different concepts, e.g., bear and fly; therefore, one decides the target concept in advance of defining it. Word definitions in terms of defining attributes of concepts cannot always be found in dictionaries. Definitions given in abridged dictionaries are usually synonyms, examples, or uses of the word in context. These also appear in unabridged dictionaries but are useless in determining the defining attributes (Markle, 1975). In arriving at the defining attributes of most concepts the concept analyzer, if not expert in the particular subject matter, uses authoritative printed materials and also may seek the assistance of subject-matter experts.

SPECIFYING THE DEFINING ATTRIBUTES

The concept analyzer specifies the defining attributes of the concept in order to identify sets of teaching examples and nonexamples (Markle & Tiemann, 1969) and also to teach students an algorithmic strategy for evaluating instances as examples and nonexamples of the concept, as will be explained later.

Those attributes which are present in every example of a concept and therefore also distinguish the concept examples from examples of all other concepts are called the defining attributes of the concept. Establishing the defining attributes of the concept and arriving at a definition of the word representing the concept proceed simultaneously during a concept analysis.

The defining attributes of observing scientifically are: (1) using one or more of the senses, (2) examining critically, (3) recording data precisely.

SPECIFYING THE VARIABLE ATTRIBUTES

The variable attributes of the concept are identified to facilitate the later selection of examples and nonexamples. Examples of the same concept vary widely on their nondefining attributes. For example, reptiles are of many different colors and sizes; fish also vary in the same colors and are of various sizes. The attributes which members of the reptile class and members of the fish class have in common and which therefore may hinder persons in discriminating between the members of the two classes are called variable attributes. In most previous reports, starting with Bruner, Goodnow, and Austin (1956), they have been called irrelevant attributes.

The first rule for identifying variable attributes is to identify those that are common to the concepts that are coordinate to the target concept. It is these attributes that are present in both the examples and nonexamples of a particular concept and that often lead to errors in classification. The second rule is to identify attributes that may be present in both the target concept and either its supraordinate or subordinate concepts. With concepts that are not part of a taxonomy, one identifies the variable attributes intuitively, selecting those that learners may incorrectly consider as defining attributes of the target concept.

The variable attributes identified for observing scientifically are: (1) the kinds of objects or events being observed, (2) the sense or senses being used, (3) the place or situation in which objects or events are being observed, (4) the method of recording data.

SELECTING ILLUSTRATIVE EXAMPLES AND NONEXAMPLES

Examples and nonexamples of the concept are needed in teaching the concept and in assessing students' learning of the concept. At least one set of examples and nonexamples is identified during the concept analysis in such a way as to ensure that errors of undergeneralization, overgeneralization, and misconception by the learner will be avoided (Markle & Tiemann, 1969; Markle, 1975). When several concepts of the same taxonomy are taught in a series of lessons, the nonexamples of any one concept are in reality examples of other concepts of the taxonomy. Using examples of concepts of the same taxonomy for nonexamples of the target concept permits the defining attributes to be excluded meaningfully from each nonexample and the variable attributes to be included meaningfully in both the examples and nonexamples.

One cannot deal with examples and nonexamples of concepts in a hierarchy as systematically as in a taxonomy since there often are neither coordinate nor supraordinate concepts. An intuitive approach is required and the emphasis is placed more on the selection of examples and nonexamples than on matching the defining and the variable attributes. Descriptions of possible examples and nonexamples of observing scientifically follow:

Example of observing scientifically (all defining attributes included and explicit): Bill looked at a marshmallow carefully, felt it, tasted it, and smelled it. Then he put it over the flame of a Bunsen burner and watched as it turned from white to black. He smelled it as it burned. After it cooled, he felt it and noticed that it felt crisp. He tasted it and

thought that it tasted like charcoal. He recorded these things in his report book.

Nonexample of observing scientifically (one or more defining attributes not included): Cecil saw the mailman deliver a box to the principal. Without looking at the label or inside the box, Cecil thought to himself, "The principal said he was going to order a new microscope for the school." Cecil saw his friend, Jim, and told him that the new microscope had arrived.

IDENTIFYING ILLUSTRATIVE PRINCIPLES

Concepts are useful to an individual in several ways, including in understanding principles that incorporate the concepts. Understanding principles involving cause-and-effect and correlational relationships among concepts, in turn, makes it possible to explain many events and also, in some cases, to predict and to control (Bruner, 1960; Klausmeier, Ghatala, & Frayer, 1974). Understanding principles facilitates the solution of problems. It is useful, therefore, to identify illustrative principles of which the target concept is a part to promote transfer of concept learning to the understanding of principles. Illustrative principles related to observing scientifically follow.

Illustrative Principles Involving Observing Scientifically:

1. Observing objects and events is prerequisite for drawing inferences regarding them.
2. Using more than one of the senses in observing objects and events increases the probability of gaining more precise information.

3. Quantitative observation permits the drawing of more precise inferences than does qualitative observation.

Examination of the principles indicates that each one expresses a relationship between the target concept and another one in the taxonomy or hierarchy, between the target concept and one or more of its defining attributes, or between the target concept and a less closely related concept. There appear to be no rules for arriving at a set of illustrative principles. However, once a principle is identified, correct applications and misapplications can be identified and used in teaching the principle (Feldman, 1974; Katz, 1975).

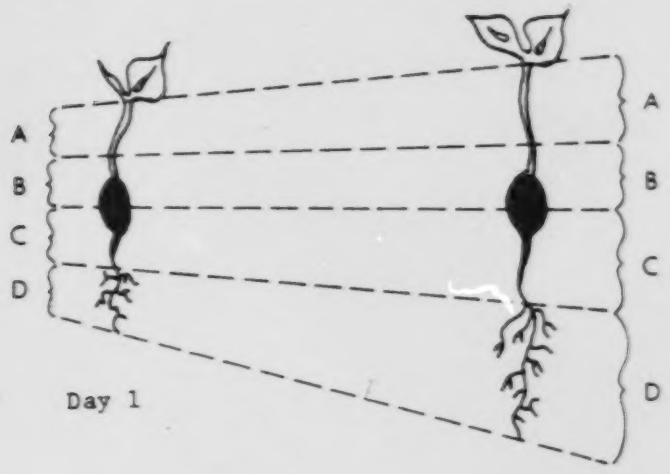
FORMULATING ILLUSTRATIVE PROBLEM-SOLVING EXERCISES

As part of a concept analysis, problem-solving exercises are formulated, the solutions of which presumably are facilitated by understanding the target concept and applying knowledge of a principle or a combination of principles. No attempt is made to make the problem-solving exercises of equal difficulty. On the contrary, a range of difficulty is preferable in the analysis so that additional examples of an appropriate level of difficulty can later be prepared for a particular target population of students.

A problem-solving exercise for observing scientifically follows.

Illustrative Problem for Observing Scientifically:

Below are drawings of a growing plant. It was observed on Day 1 and again on Day 3.



Which part grew the most in the two days?

a. the leaf
b. the stem
c. the part of the root close to the seed
d. the part of the root near the end or tip

DEVELOPING A VOCABULARY LIST

The rule for generating a vocabulary list as part of a concept analysis is to include the name of the concept and the key terms of the defining attributes. The extent to which the terms will be used in teaching a particular concept varies greatly according to the level of attainment desired. None of it may be used at the concrete level; all of it must be used at the formal level. Students' knowing the name of the concept and the names of its defining attributes correlates

positively and high with the level of concept attainment and also the uses of concepts (Klausmeier, Sipple, & Allen, 1974a, 1974b). The list for observing scientifically follows: observing, scientifically, senses, critically, examine, record, accurately, data, information, precisely.

V

DEVELOPMENT OF PROCESS-CONCEPT LESSONS

In this chapter, the rationale for use of the lessons is presented. This is followed with a brief description of the lessons and a sample of parts of one lesson. In the last part of the chapter the development of the assessment exericses that immediately follow the lesson is described.

RATIONALE FOR THE LESSONS

Printed instructional materials to teach concepts can be used effectively with students who can read and who have already attained the target concept at the beginning classificatory level. The materials may be used to aid students to classify more correctly and extensively at the classificatory level, to attain a beginning formal level, and to attain an adult formal level.

Sufficient knowledge has accrued from preceding studies (Bernard, 1975; Klausmeier, Schilling, & Feldman, 1976; McMurray, Bernard, & Klausmeier, 1975) and others to be reported that the instructional conditions which follow are regarded as fully validated. It is clear also that the conditions which follow can be incorporated in printed materials.

1. Establish an intention to learn concepts. An intention to learn concepts is developed before the student tries to learn a particular concept. This is done by telling the students that they will be learning concepts, by pointing out important features of concept learning, or by describing the concept population comprising the taxonomy or hierarchy. Amster (1966), Fredrick and Klausmeier (1968), Kalish (1966), Laughlin, Doherty, and Dunn (1968), and Osler and Weiss (1962) all reported facilitative effects from instructions designed to establish an intent to learn concepts. Ausubel (1968) has demonstrated the facilitative effects of advance organizers on learning various kinds of new materials and Bernard (1975) has shown the facilitative effects in connection with a taxonomy of concepts.

Establishing an intention to learn concepts (as opposed, for example to establishing a set to memorize the individual instances) activates several operations essential to attaining concepts at the classificatory and formal levels. First, such instructions may alert the learners that they should attend to and discriminate the attributes of instances. Second, such instructions may engage the learners in an active search for the attributes which distinguish instances from noninstances. At the outset, then, the learning is engaged actively in searching behaviors directed towards learning the particular concept or concepts to a higher level of attainment.

2. Elicit student verbalization of the concept name and the defining attributes. To accomplish this, a vocabulary list is presented at the beginning of a series of lessons, and the students are taught to recognize the words.

Having the concept and attribute labels greatly facilitates carrying out both inductive and deductive operations at the formal level of attainment, including formulating, remembering, and evaluating hypotheses and assimilating and processing information that is presented verbally in an expository approach to instruction. Linguistic codes are maximally efficient for carrying out the sequential information processing which is involved in inferring concepts from examples and nonexamples inductively, and also for assimilating the information as presented in a definition, a set of verbal examples and nonexamples of the concepts, and verbal explanations or descriptions. Clark (1971) reported facilitation of concept attainment through giving the label of the concept and/or the labels of its defining attributes. When printed material is used, the students must not only be able to use the terms orally, they must also be able to read them.

3. Emphasize the defining attributes of the concept by drawing the students' attention to them. Giving students the names of the defining attributes of the concept in the concept definition is insufficient for teaching them to discriminate the defining attributes and to use them subsequently in differentiating examples from nonexamples of the concept. Frayer (1970) found that emphasizing the defining attributes by verbal cues improved immediate concept learning and later transfer and retention.

Merrill and Tennyson (1971) compared the effects of a concept definition, a definition of the attributes of the concept, a rational set of examples and nonexamples, and attribute prompting singly and in various combinations. Attribute prompting was found to be more facilitative than a definition of the concept or definitions of the attributes. The

most effective condition included all four variables. Clark (1971) reported that a large majority of researchers found beneficial effects of directing the students' attention to the concept attributes and/or the conceptual rule; also, pointing out the attributes and rules to the students yielded better results than permitting the students to discover them themselves.

4. Present a definition of the concept in terms of defining attributes, stated in vocabulary appropriate to the target population. Providing students with the concept definition eliminates the operations involved in identifying the defining attributes of the concept and inferring the concept from experiences with examples and nonexamples of the concept. However, simply presenting students with the concept definition does not insure concept attainment--the students may merely acquire a rotely memorized string of verbal associations. To insure that the students acquire a concept and not a string of words, at a minimum they must also be presented with concept examples and nonexamples to classify. Correct classification requires that the students differentiate examples from nonexamples on the basis of the defining attributes contained in the concept definition. Thus, both discriminating the attributes of instances and evaluating instances to determine whether or not they exhibit the defining attributes contained in the definition are operations involved after the student is given the concept definition.

The facilitative effect of a definition varies as a function of several variables including the number of rational sets of examples and nonexamples presented. In a controlled experiment with fourth-grade students Klausmeier and Feldman (1975) found a definition to have about the same amount of facilitation as one rational set of examples and

nonexamples. A definition combined with one rational set was more effective than a definition or a rational set alone; and a definition combined with three rational sets showed greatest facilitation.

A definition must be stated in appropriate terminology. Feldman and Klausmeier (1974) found a common usage definition to be more effective than a technically stated definition with fourth-graders; whereas the technically-stated definition was more effective with eighth-graders. Feldman (1972) and Merrill and Tennyson (1971) also reported a facilitative effect for definitions.

5. Provide a strategy for differentiating examples and nonexamples. Bruner, Goodnow, and Austin (1956) described various reception and selection strategies that students learn incidentally, without instruction concerning the strategies. Fredrick and Klausmeier (1968) and Klausmeier and Meinke (1968) reported the facilitative effects of teaching students strategies for attaining concepts. Bernard (1975), McMurray, Bernard, and Klausmeier (1975), and Klausmeier, Schilling and Feldman (1976), incorporated the same strategy for evaluating instances as examples or nonexamples in their experimental lessons with excellent results. Teaching the efficient strategy in the printed material insures that an effective strategy will be learned and eliminates much trial-and-error learning. Providing for the students to use the strategy in identifying examples and nonexamples and providing feedback promotes active learning of the strategy. In this connection, students of low socioeconomic status do not learn mature conceptualizing skills related to certain subject matters unless they receive appropriate instruction during the school years in those subject matters (Nelson & Klausmeier, 1974).

6. Present at least one rational set of properly matched examples and nonexamples of varying difficulty level.

A rational set of examples and nonexamples as defined by Markle and Tiemann (1969) is a set that has as many nonexamples in it as there are defining attributes of the concept (each nonexample should have one defining attribute) and as many examples as there are variable attributes (each example should have one variable attribute). A sufficient number of sets should be included so that students learn the concept to the level desired.

In presenting each rational set, each example should be matched with a nonexample having the same variable attribute or attributes. The difficulty level within a set should range from easy to difficult but be appropriate to the target population of students. The use of rational sets effectively reduces and eventually eliminates errors of under-generalization, overgeneralization, and misconception (Feldman, 1972; Markle & Tiemann, 1969; Merrill & Tennyson, 1971; Swanson, 1972; Tennyson, 1973; Tennyson, Woolley, & Merrill, 1972). It is noted that matching examples and nonexamples on difficulty and also on both variable and defining attributes cannot be dealt with as precisely with all concepts as those reported in the preceding experiments.

7. Provide for feedback concerning the correctness and incorrectness of the responses. Clark (1971), Frayer and Klausmeier (1971), Markle (1975), and Sweet (1966) report the desirable effects of feedback to students. Clark (1971), for example, reported that concept attainment improved as the frequency of feedback increased up to 100 percent. Frayer and Klausmeier (1971) reported from their survey of research that

feedback should be provided after every response, but that it is more important after an incorrect response. Feedback which tells the students not only that a response or hypothesis is wrong but which also enables them to infer how it is wrong and how to correct it is particularly helpful.

DESCRIPTION OF LESSONS

Each lesson in the present experiment was modeled after that used in prior lessons on equilateral triangle (McMurray, Bernard, & Klausmeier, 1975) and tree (Klausmeier, Schilling, and Feldman, 1976). The effects of these lessons were noted earlier in Chapter 2. While the sequence of presenting items in the lesson has not been established empirically, the following sequence of elements based on rational analysis was used (1) provide an interesting introduction; (2) present the key vocabulary, (3) teach the defining attributes of the concept; (4) teach the definition of the concept; (5) provide rational sets of examples and nonexamples of the concept; (6) teach a strategy for evaluating examples and nonexamples of the concept. In this teaching process, the learner must evaluate examples and nonexamples; (7) provide questions in each part 3 - 6 above with answers given immediately following, thereby providing feedback to the student.

As a means of focusing and holding student attention, a story format with characters is used in each lesson to present the information and instructions. The characters are represented in line drawings. Also, many of the examples and nonexamples are presented in drawings rather than in verbal statements.

Parts of the lesson on observing scientifically follow to illustrate the elements of a lesson.

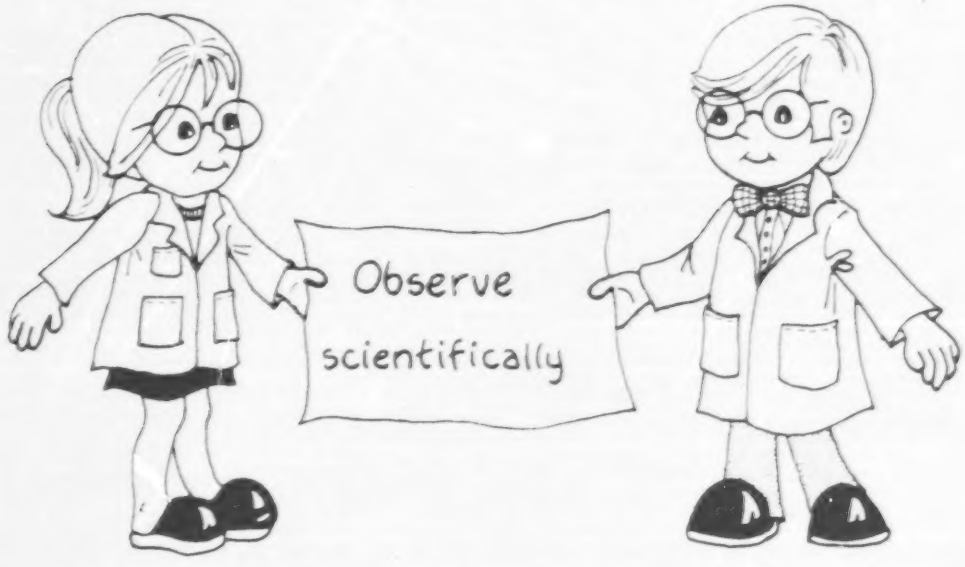
1. Introduction to lesson on observing scientifically:

Cecil is a scientist. He works in a laboratory. Once upon a time Cecil was not a good scientific observer. He did not observe the way a scientist should observe. If something in a test tube fizzed, he didn't hear it. If something in his experiment changed color, he didn't see it. If something burned, he didn't smell it.

One day Cindy, another scientist, had a talk with Cecil. She said, "Cecil, scientists do many things. One of the most important things that they do is:

OBSERVE SCIENTIFICALLY

"By observing scientifically," said Cindy, "We learn information that will help us in our work. It is very important that we learn how to observe scientifically!"



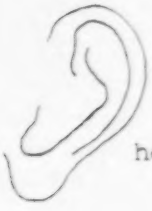
2. Key vocabulary from lesson on observing scientifically:

Cindy said:

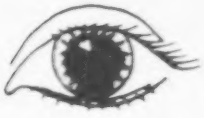
To observe scientifically, a person must:

USE ONE OR MORE OF THE SENSES

The five senses we use in observing scientifically are:



hearing



seeing

touching

tasting

smelling

Sometimes we use all five senses in observing scientifically.

3. Presentation of defining attributes from lesson on observing scientifically:

In this lesson, Cindy is going to teach us to observe scientifically.

To OBSERVE SCIENTIFICALLY, we must:

1. Use one or more of our senses.
2. Examine something carefully.
3. Accurately record information about what is observed.

You and Cecil will learn about these three things by looking at pictures and reading about them. You will be asked to do things and to answer questions about what you are learning. After you answer the questions you will see the right answers. As you are reading this lesson, REMEMBER the three things that we do when we OBSERVE SCIENTIFICALLY. Copy these three important things on the lines below:

To OBSERVE SCIENTIFICALLY, we must:

1. _____

_____

2. _____

_____

3. _____

_____

_____

4. Presentation of definition from lesson on observing scientifically:

When we put together the three important things about observing scientifically, we make the definition of observing scientifically.

Here is the definition of observing scientifically.

READ IT CAREFULLY.

OBSERVING SCIENTIFICALLY: Using one or more of the senses tc examine something carefully and to accurately record information about what is observed.

On the next pages are some stories about Cecil Scientist and observing scientifically. Each story has a beginning and two endings. In one ending Cecil is observing scientifically. In the other ending, Cecil is not observing scientifically.

While you are reading the stories, think about the three things a person must do to observe scientifically.

5. Part of a rational set of examples and nonexamples from lesson on observing scientifically:

STORY 1:

Cindy told Cecil to observe a ten-day-old plant scientifically. Here are two endings to the story about the plant. Read both endings.

Ending 1

Cecil glanced at the plant for a few seconds. Then he wrote in his report book, "It is pretty small and kind of green."

Ending 2

Cecil looked at the plant carefully, felt its leaves, and measured it with a ruler. Then he wrote in his report book, "The ten-day-old plant is three inches high. It has four leaves that are light green in color, smooth, and shiny. Its stem is very straight."

Let's talk about it!

In Ending 2, Cecil observed scientifically. He used his senses to examine the plant carefully. He accurately recorded information about what he observed. In Ending 1, Cecil was not observing scientifically. He used his sense of seeing, he accurately recorded information about the plant, but he did not examine it carefully.

6. Presentation of strategy for evaluating examples and nonexamples from lesson on observing scientifically:

How do you know if someone is OBSERVING SCIENTIFICALLY? In the next pages you will be reading more stories about Cindy and Cecil Scientist. In some of the stories, Cecil is observing scientifically. In some of the stories he is not observing scientifically. You can decide if he is observing scientifically by answering these three questions:

1. Did the person use one or more of the senses?
2. Did the person examine something carefully?
3. Did the person record information accurately about what was observed?

If you can answer YES to all three of the questions, then the person in the story was observing scientifically. If you answer NO to one or more of the questions, the person in the story was not observing scientifically.

7. Illustration of question and feedback technique from lesson on observing scientifically:

THINGS TO DO:

Use the words in the list to fill in the blanks in the sentences below. Choose the right word for the right blank.

carefully
senses
Use
Record
Examine
accurately

To observe scientifically, a person must do three things:

1. _____one or more of the _____.
2. _____something_____.
3. _____information _____about what is observed.

PLEASE TURN THE PAGE AND LOOK AT THE ANSWERS.

ANSWERS:

To observe scientifically, a person must do three things:

1. Use one or more of the senses.
2. Examine something carefully.
3. Record information accurately about what is observed.

IF YOU MADE A MISTAKE, GO BACK NOW AND CORRECT YOUR ANSWER.

Each lesson is designed to teach a particular concept. Since the lesson includes among other things the defining attributes of the particular process, these defining attributes if understood should enable the learner to discriminate reliably between the process of observing scientifically and the other processes of the particular published curriculum.

Some of the examples and nonexamples included in each lesson are intended to be easy so that the learner will not be faced with a difficult task of recognizing examples or nonexamples. Thus, the lesson is presumed to serve well as an advance organizer for the set of curricular lessons that are intended specifically to teach children to observe the various scientific phenomena scientifically.

DEVELOPMENT OF THE PROCESS-CONCEPT ASSESSMENT

The process concept assessments are constructed to measure the level of conceptual attainment on each of the SAPA process concepts taught in the process concept lessons. The construction of the assessment for observing scientifically was based on the CLD model. Items were written by project personnel familiar with the CLD model and by a test construction specialist. The paper-pencil test intended for group administration used a multiple-choice answer format. The items were developed to determine whether a child was at the classificatory or the formal level of conceptual attainment. Two scores were computed: total number of items correct at the classificatory level and total number of items correct at the formal level. A total score combining these subscales was also computed.

The process concept assessment for observing scientifically is provided in Appendix E. Items 1 through 8 assess the child's ability to classify examples and nonexamples of observing scientifically. Items 9 through 11 assess the child's ability to discriminate the three defining attributes of observing scientifically. Items 12 through 14 assess whether the child can name the defining attributes. Items 15 through 17 assess the ability to evaluate examples of observing scientifically in terms of defining attributes. Finally, Item 18 assesses recognition of the definition of the process-concept.

The assessment for observing scientifically was piloted with a small group of children representing high, medium, and low achievers. Following the pilot tryout, revisions were made in the content and the directions.

VI

PROCESS-CONCEPT LESSON EXPERIMENT

In the early spring of 1975, an experiment was conducted to assess the effectiveness of a lesson on the process-concept observing scientifically. Samples of students in Schools A and C received the lesson Observing Scientifically, the related assessment, and a brief questionnaire to assess students' attitudes towards this type of lesson. Each teacher of levels 5 and 6 read the lesson and assessment aloud to the children while level 7 students read the lesson and assessment themselves. Members of the project staff observed administrations of the lesson and assessment at each level and noted few difficulties.

In both schools, some students received both the lesson and assessment (experimental) while other students received the assessment only (control). In School A teachers randomly selected students within classes who were to receive either the experimental or control treatment. Because of scheduling difficulties, students in School C were given either the experimental or control treatment as an entire class.

Because of differences in reading ability among the students, the Vocabulary and Comprehension subtest scores of the Gates-MacGinitie Reading Test were used as covariates for the analysis of covariance. The

dependent variables for the analysis were the classificatory and formal subtest scores on the process-concept lesson Observing Scientifically. The data for those students who had scores on both covariates were included in analysis.

The F-ratios for both classificatory (see Table 2) and formal (see Table 4) subtests were significant ($p < .001$) for combined grades at School C.

TABLE 2

RESULTS OF ANALYSIS OF COVARIANCE OF PROCESS-CONCEPT LESSON, OBSERVING SCIENTIFICALLY, FOR SCHOOL C ON CLASSIFICATORY SUBSCALE COMBINING LEVELS 5, 6, AND 7

Source of Variation	df	SS	MS	F	p less than
Treatment	1	33.29	33.29	22.41	.001
Within Groups	167	248.10	1.49		
Total*	172	335.20			

*The total sum of squares includes variation attributable to covariates and blocking variables.

TABLE 3

RESULTS OF ANALYSIS OF COVARIANCE OF PROCESS-CONCEPT LESSON, OBSERVING SCIENTIFICALLY, FOR SCHOOL C ON FORMAL SUBSCALE COMBINING LEVELS 5, 6, AND 7

Source of Variation	df	SS	MS	F	p less than
Treatment	1	58.92	58.92	19.43	.001
Within Groups	167	506.40	3.03		
Total*	172	900.70			

*The total sum of squares includes variation attributable to covariates and blocking variables.

The F-ratios for both classificatory (see Table 4) and formal (see Table 5) subtests were significant (classificatory with $p < .01$ and formal with $p < .001$) for fourth-grade students in School A. These results support the effectiveness of the process-concept lesson in increasing the child's ability to classify instances of the concept observing scientifically as well as improving performance at the formal level.

Teachers were given a six-item questionnaire on the lesson and assessment. All teachers felt the lesson met its objectives. Only one teacher felt that the lesson was too lengthy, and only one teacher felt the vocabulary was too difficult. In addition, students completed a four-item questionnaire on the lesson. The results are presented in Table 6. Instructions and test questions were modified to eliminate problems cited by the teachers and the students.

TABLE 4

RESULTS OF ANALYSIS OF COVARIANCE OF PROCESS-CONCEPT LESSON, OBSERVING SCIENTIFICALLY, FOR SCHOOL A ON CLASSIFICATORY SUBSCALE FOR LEVEL 5

Source of Variation	df	SS	MS	F	p less than
Treatment	1	18.28	18.28	13.19	.01
Within Groups	127	176.10	1.39		
Total*	130	200.90			

*The total sum of squares includes variation attributable to covariates and blocking variables.

TABLE 5

RESULTS OF ANALYSIS OF COVARIANCE OF PROCESS-CONCEPT LESSON, OBSERVING SCIENTIFICALLY, FOR SCHOOL A ON FORMAL SUBSCALE FOR LEVEL 5

Source of Variation	df	SS	MS	F	p less than
Treatment	1	63.28	63.28	19.74	.001
Within Groups	127	407.10	3.21		
Total*	130	613.70			

*The total sum of squares includes variation attributable to covariates and blocking variables.

TABLE 6

RESULTS OF STUDENT QUESTIONNAIRE ON THE
PROCESS-CONCEPT LESSON OBSERVING SCIENTIFICALLY

Question	SCHOOL A Level 5	SCHOOL C Level 5	SCHOOL C Level 6	SCHOOL C Level 7
	%	%	%	%
1. How interesting was the lesson?				
a. Very interesting	60	65	58	36
b. Kind of interesting	35	35	35	62
c. Not at all interesting	5	0	7	3
2. Were the directions written so that you knew exactly what to do?				
a. Yes	70	87	98	100
b. No	30	13	2	0
3. Was the lesson hard to read?				
a. Yes	16	13	12	5
b. No	84	87	88	95
4. Did this lesson teach you anything new?				
a. I learned lots of new things	56	56	47	44
b. I learned a few new things	44	43	40	56
c. I did not learn anything new	0	2	14	0

VII

PLANNING MECHANISMS AND RELATIONSHIPS WITH SCHOOLS

In this chapter, a description is given of securing participation with the central office staff of the schools. Also the planning sessions and workshops conducted with schools during the 1974-75 school year are summarized.

SECURING CENTRAL OFFICE PARTICIPATION

In an initial meeting in April of 1974 with school central office personnel and R & D Center project staff, the general outline of the proposed study was presented by the principal investigator of the project to the superintendent of schools, the director of elementary education, and the system's science coordinator. Central office participation in the study was secured in that initial meeting, and a second meeting to be held in September of 1974 was scheduled with the purposes of identifying the experimental schools and the matched control schools and specifying the assessment procedures. Central office participants in the second meeting included personnel given above as well as the director of pupil services. In that second meeting it was decided that the science coordinator be the primary school system contact with the R & D Center staff in the cooperative project.

WORKSHOPS WITH SCHOOL PERSONNEL DURING 1974-75 SCHOOL YEAR

A total of seven workshops were conducted during the second semester of the 1974-75 school year. Each two-hour workshop session occurred outside regular school hours. The specific dates and main topics of each session as well as the participants are presented in Table 7. In addition, five six-hour sessions were held during one week in June of 1975 with the principals and unit leaders of the experimental schools, the science coordinator, and the R & D Center project staff. During these sessions, final revisions were made in the following materials: Attitude Towards Science measure, content-specific tests, process-concept lessons, and assessments for observing scientifically, classifying, inferring, and predicting, and the teacher logs. It was agreed that a resource file of supplementary science materials be developed to cross-reference various published texts. This file would enable teachers to refer students to related information, either as an enrichment exercise or for basic reading during SAPA lesson instruction. Finally, the specific details in differentiating instruction were outlined. (This information about grouping for differentiated instruction is provided in Appendix F).

TABLE 7

DATES, MAIN TOPICS, AND SCHOOL PERSONNEL PARTICIPANTS FOR WORKSHOPS CONDUCTED DURING 1974-75 SCHOOL YEAR

Date	Main Topic	Participants
February 13, 1975	Teacher ratings of student performance Content-specific test scores	experimental school staffs
February 25, 1975	Instruction by process block Process-concept analysis of observing scientifically	experimental school staffs
March 13, 1975	Process-concept lesson on observing scientifically	experimental school staffs
March 20, 1975	Use of content-specific test scores Use of process-concept lessons	experimental school staffs
April 10, 1975	Instructional programming model (IPM) Specific procedures for conducting experiment on process-concept lesson experiment Observing Scientifically	experimental school staffs
April 22, 1975	Specific instructional procedures to be put into effect during 1975-1976 school year in the two schools in the experimental condition	experimental school staffs
May 6, 1975	Specific instructional sequences for SAPA blocks of lessons for the 1975-1976 school year Information gathering procedures during the 1975-1976 school year	experimental school and control school staffs

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APPENDIX A

ATTITUDE TOWARDS SCIENCE
(ATS) MEASURE

ATS

Name _____ Level _____
(last) (first)

School _____ Teacher _____

	Agree	Slightly Agree	Slightly Disagree	Disagree
1. Science is a waste of time.				
2. I can hardly wait for the school day to be over.				
3. Science is interesting.				
4. I would like to get a microscope or chemistry set for Christmas or my birthday.				
5. Science is a good hobby.				
6. I think science classes are too long.				
7. I like anything that has to do with science.				
8. I wish we spent more time studying plants and animals.				
9. I like science books more than any other kind of books.				
10. I wish that history books were more interesting.				

	Agree	Slightly Agree	Slightly Disagree	Disagree
11. I could do very well without science.				
12. I wish that I could write better stories.				
13. Science is a good subject.				
14. I would like to learn to speak a foreign language well.				
15. I am not interested in science.				
16. I would enjoy going to school during the summer if I could study science.				
17. If it has to do with science, forget it! I hate science.				
18. I would like to be a scientist when I grow up.				
19. I like to read the newspaper.				
20. There are lots of things I'd rather do than study science.				
21. I enjoy math better than spelling.				
22. I have no desire to study science.				
23. I can hardly wait for math class.				
24. I only take science because I have to.				

APPENDIX B

TEACHER LOGS FOR EXPERIMENTAL
SCHOOLS AND FOR CONTROL SCHOOLS

CONTROL SCHOOLS

TEACHER LOG

Teacher _____ School _____

Level _____ SAPA lesson _____

Dates lesson taught: from _____ to _____

	(minutes)
Total number of students taught	Total time to teach lesson and assess performance

Please check those experiences which involved the total class; otherwise indicate the number of students participating:

SAPA EXPERIENCES	
SAPA Booklet Activity # 1	☐
Activity # 2	☐
Activity # 3	☐
Activity # 4	☐
Activity # 5	☐
Activity # 6	☐
Activity # 7	☐
Generalizing Experience	☐
Appraisal	☐
Competency Measure	☐
Other activity (specify):	☐

Use N/A to indicate which experiences do not apply to this lesson.

Teacher _____ Level____ SAPA lesson_____

Dates lesson taught: from _____ to _____

TOTAL STUDENTS	GROUP	TOTAL MINUTES TAUGHT

EXPERIMENTAL SCHOOLS

Teacher Log

(A) INTRODUCTION OF LESSON

☐ Limited ☐ Average ☐ Detailed ☐

(B) TEACHER DEMONSTRATION

☐ Limited ☐ Average ☐ Detailed ☐

(C) SAPA LESSON ACTIVITIES

☐ Large group ☐ Small group ☐ Individual ☐

(D) ASSESSMENT : SAPA TEST

MASTERY AT_____ % level ⬡

NON-MASTERY ⬡

(G) REINFORCEMENT / ENRICHMENT

☐ READING IN SUPPLEMENTARY TEXTS

____Houghton-Mifflin (MAPS):

____Follett:

____Addison-Wesley:

____Other:

☐ MEDIA CENTER INSTRUCTION (Films, tapes, kits, etc.)

☐ TUTORING OF OTHER STUDENTS

☐ INDIVIDUAL PROJECTS / EXPERIMENTS

☐ OTHER (SPECIFY):

(E) RE-TEACH

☐ USING SAPA LESSON

☐ USING TUTORS

☐ USING RESOURCE TEXTS

____Houghton-Mifflin (MAPS):

____Follett:

____Addison-Wesley:

____Other text:

☐ OTHER (SPECIFY):

(F) RE-ASSESSMENT ☐

APPENDIX C

SUMMARY STATISTICS FOR TRYOUT VERSION
CONTENT-SPECIFIC TESTS

TABLE C-1

SUMMARY STATISTICS FOR TRYOUT VERSION
CONTENT-SPECIFIC TESTS: LEVEL 5

Test	Number of items	N	$\bar{X}$	S.D.
1 Observing Animal Response to Stimuli	12	91	8.24	1.58
2 Rate of Change of Position	21	97	12.15	3.45
3 Dividing to Find Rates and Mean	16	96	6.83	2.62
4 Metersticks, Money, and Decimals	22	91	11.30	3.00
5 Tempersture and Thermometers	16	90	7.00	2.39
6 Measuring Volumes	15	96	7.25	1.98
7 Describing the Motion of a Revolving Phonograph Record	22	94	10.97	3.19
8 Measuring Drop by Drop	12	97	6.45	2.18
9 Measuring Evaporation of Water	14	94	8.49	1.84
10 The Color Wheel--An Order Arrangement	16	90	6.87	2.71
11 Separating Materials from Mixtures	13	97	8.45	2.50
12 Using Maps	17	96	9.47	2.08
13 Surveying Opinion	17	97	8.71	3.17
14 Describing the Motion of a Bouncing Ball	14	97	8.41	2.12
15 Observations and Inferences	13	95	6.01	2.30
16 Tracks and Traces	13	96	6.05	1.88
17 The Displacement of Water by Air	10	97	3.71	2.04

TABLE C-2

SUMMARY STATISTICS FOR TRYOUT VERSION
CONTENT-SPECIFIC TESTS: LEVEL 6

Test	Number of items	N	$\bar{X}$	S.D.
1 Magnetic Poles	17	93	9.82	3.02
2 Observing Growth from Seeds	13	93	7.74	1.93
3 Observing Falling Objects	11	90	5.91	1.64
4 2-D Representing of 3-D Figures	13	89	8.20	2.39
5 Relative Position and Motion	10	90	4.58	1.70
6 Describing and Representing Forces	19	90	9.20	2.69
7 Using Punch Cards	10	86	6.87	1.75
8 Describing Location	14	91	6.84	2.37
9 Reporting and Investigating Writing	14	58	8.86	2.50
10 Suffocating Candles	10	89	4.69	1.49
11 Loss of Water from Plants	10	90	4.23	1.75
12 Inferring Connection Patterns in Electrical Circuits	13	89	6.85	2.35
13 Shape of Cut Things	14	91	5.66	2.21
14 Rolling Cylinders	20	90	11.81	3.70
15 Upward Movement of Liquids	13	86	7.79	2.29
16 Guinea Pigs in a Maze	13	89	7.92	2.88
17 Observations and Hypotheses	13	90	5.78	2.19

APPENDIX D

SAMPLE CONTENT-SPECIFIC TEST

Level 5
Test 8

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Published by the Wisconsin Research and Development Center for Cognitive Learning, supported in part as a research and development center by funds from the National Institute of Education, Department of Health, Education, and Welfare. The opinions expressed herein do not necessarily reflect the position or policy of the National Institute of Education and no official endorsement by that agency should be inferred.

Center Contract No. NE-C-00-3-0065

1. "The curved upper surface of water in a graduated cylinder." This is a definition of:

   a. ellipse
   b. volume
   c. membrane
   d. meniscus
   e. *I don't know.*

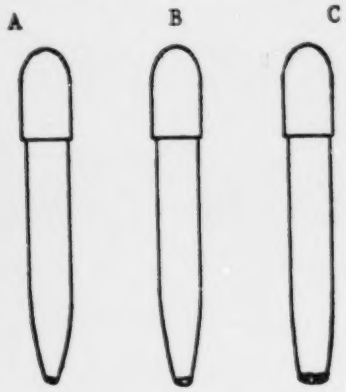
2. "To thin down or weaken by mixing with water or other liquid." This is a definition of:

   a. dilute
   b. saturate
   c. contract
   d. concentrate
   e. *I don't know.*

3. The smaller the diameter of the tip of a dropper...

   a. the more the dropper will hold
   b. the less the dropper will hold
   c. the larger the drop it will form
   d. the smaller the drop it will form
   e. *I don't know.*

Look at the three droppers shown below.



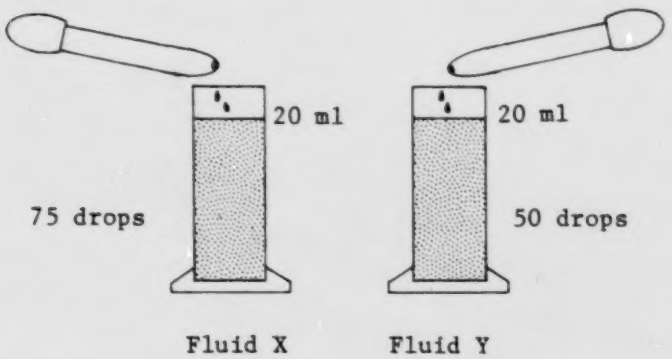
4. If you squeezed each of these droppers the same way, which dropper would form the largest drop of water?

   a. Dropper A
   b. Dropper B
   c. Dropper C
   d. any one of them
   e. *I don't know.*

5. Each of the droppers above was used to fill different 2 ml flasks. It took 20 drops from Dropper A to fill the flask, it took 15 drops from Dropper B, and it took 10 drops from Dropper C. What can you say about the droppers?

   a. Different droppers make different size drops.
   b. Dropper A can hold more water than Dropper C.
   c. All three droppers have the same tip size.
   d. All droppers make the same size drops.
   e. *I don't know.*

6. Below are drawings of two flasks of fluid.



A 20 ml flask was filled with Fluid X using a dropper; it took 75 drops. Another 20 ml flask was filled with Fluid Y using the same dropper. It took 50 drops. Which fluid produces drops of greater volume?

a. Fluid X
b. Fluid Y
c. Both fluids produce drops of the same volume.
d. *I don't know.*

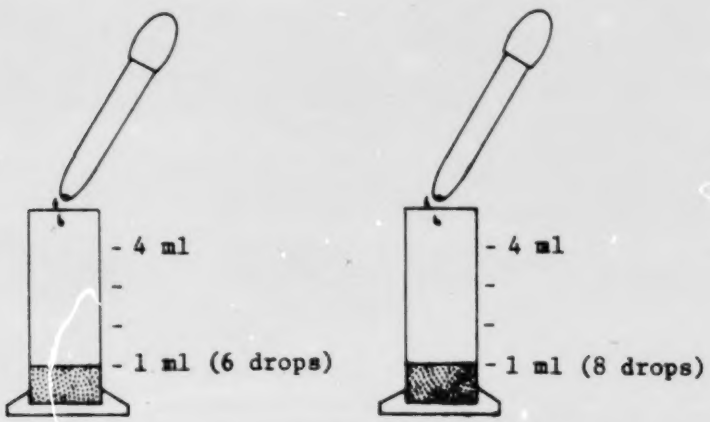
7. It takes 13 drops from a dropper filled with Fluid Z to make a volume of <u>one</u> milliliter. How many drops of Fluid Z would it take to make a volume of <u>three</u> milliliters?

a. 3 drops
b. 13 drops
c. 16 drops
d. 39 drops
e. *I don't know.*

8. It takes 10 drops of Fluid X to make one milliliter of volume. Using the same dropper, it takes 15 drops of Fluid Y to make one milliliter of volume. If you want to fill up a beaker using as <u>few</u> drops as possible, which fluid would you choose?

   a. Fluid X
   b. Fluid Y
   c. Either X or Y will work well when you are in a hurry.
   d. *I don't know.*

9. It takes 6 drops of Fluid X to make one milliliter of volume. It takes 8 drops of Fluid Y to make one milliliter of volume.

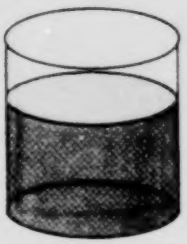


How many drops would you have to have to make 4 milliliters of <u>each</u> fluid?

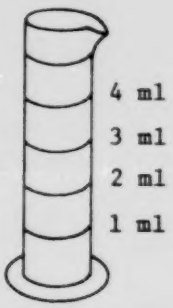
   a. 16 of X and 12 of Y
   b. 16 of X and 24 of Y
   c. 24 of X and 32 of Y
   d. *I don't know.*

10. You are going to use the following things in an experiment:

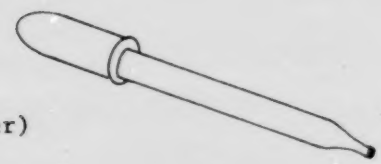
(a beaker partly filled with water)



(a graduated cylinder marked off in milliliters)



(a dropper)



How can you measure out exactly .5 ml of water?

a. Pour some water into the cylinder and guess where .5 ml would be.
b. Count the number of drops needed to fill the cylinder and divide by two.
c. Count the number of drops to reach the 1 ml mark and divide by two.
d. *I don't know.*

APPENDIX E

PROCESS-CONCEPT ASSESSMENT
FOR OBSERVING SCIENTIFICALLY LESSON

PART I

Some of the stories below describe scientific observing. Some of the stories do not. You must read each story carefully and then decide whether or not the person observed scientifically.

If the story describes scientific observing, blacken in the space for "Yes" on your answer sheet; if the story does not, blacken in the space for "No."

1. Sandra raised a pig for the county fair. Each week she weighed her pig carefully. Then she recorded the pig's weight accurately on a chart.

2. Mike ran quickly across the playground. He didn't notice his best friend playing on the swings.

3. Pam baked 4 kinds of cookies. She asked her mother to tell which kind had lemon in it. Her mother tasted each cookie and wrote down whether or not it had lemon in it.

4. Jack went for a walk in the woods. Each time he saw a bird, he stopped to look at it carefully and to take its picture.

5. Sally stopped in the park to look at some flowers. She rolled in the grass. Then she ran home for supper.

6. Bob had to do the grocery shopping on his way home from school. He wanted to remember what groceries he needed, so he made a list.

7. Bill painted his bike orange. He mixed red and yellow paint to get orange.

8. Pat planted 2 different kinds of beans in her garden. Each week she measured the beans carefully. She made a chart to show how much each kind had grown.

PART II

For the following questions, blacken in the correct letter on your answer sheet.

9. Which of the following tells about someone recording information accurately?

   a. Tom looked up information about African wildlife.

   b. Mary drew pictures of 3 different types of clouds in the sky.

   c. Pam collected several new stamps for her album.

   d. Jack listened to the sounds his baby brother was making

10. Which of the following tells about someone using one of the senses?

   a. Larry thought about eating a big cheese and sausage pizza.

   b. Robin took a short nap after a bicycle ride.

   c. Rick hurried home from school to play baseball with his friends.

   d. Susan smelled cookies as she walked into the kitchen.

11. Which of the following tells about someone examining things carefully?

   a. Barbara dumped a bag of colored marbles on the floor and counted how many of each color she had.

   b. Larry went to the library to find a book on cars and chose the book Transportation in the 1800's. When he got home he discovered it wasn't about cars.

   c. Patty didn't notice that her shoes were muddy when she walked into the hall.

   d. Sara went to the store to get some bananas. When she returned home, she discovered that half of the bananas were spoiled.

12. Look carefully at Cartoon A and Cartoon B.

Cartoon A

Cartoon B

Which of the following tells what is happening in Cartoon A but not in Cartoon B?

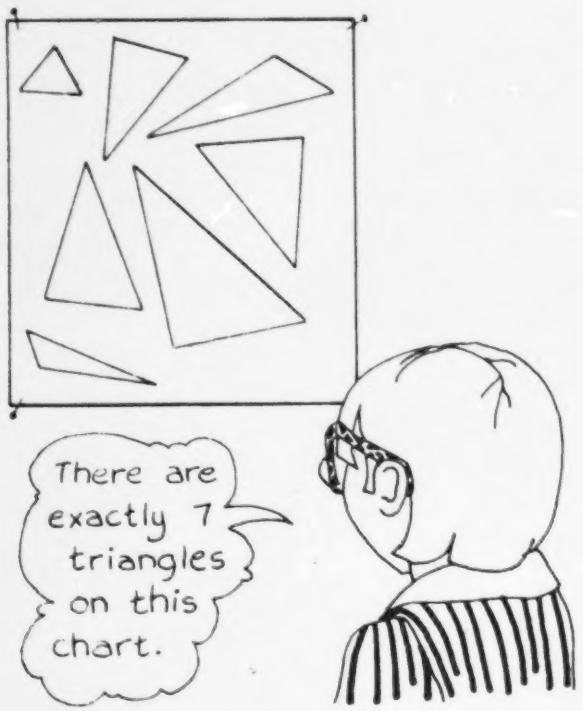
a. The girl is recording information in Cartoon A but not in B.

b. The girl is making a prediction in Cartoon A but not in B.

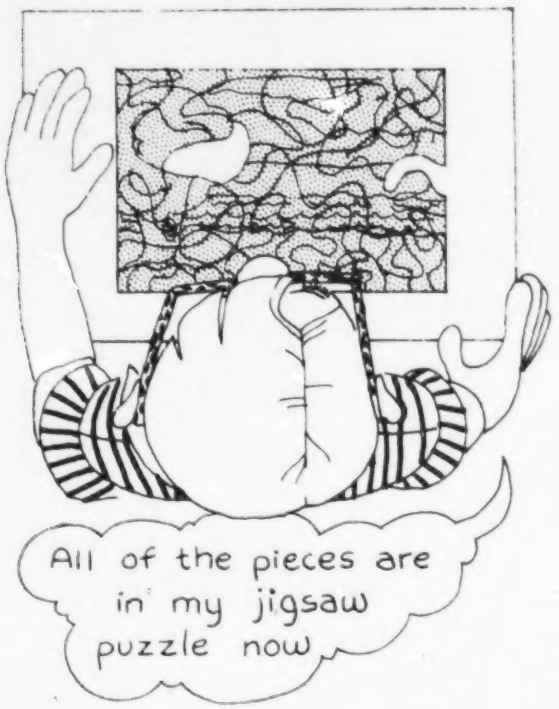
c. The girl is keeping track of information in Cartoon A but not in B.

d. The girl is recording information accurately in Cartoon A but not in B.

13. Look carefully at Cartoon A and Cartoon B.



Cartoon A



Cartoon B

Which of the following tells what is happening in Cartoon A but not in Cartoon B?

a. The boy is recording information carefully in Cartoon A but not in B.

b. The boy is examining things carefully in Cartoon A but not in B.

c. The boy is keeping track of information in Cartoon A but not in B.

d. The boy is making an inference in Cartoon A but not in B.

14. Look carefully at Cartoon A and Cartoon B.

Cartoon A

Cartoon B

Which of the following tells what is happening in Cartoon A but not in Cartoon B?

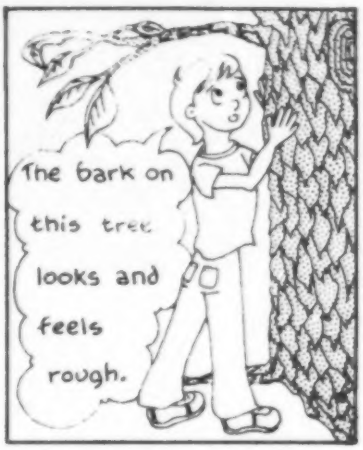
a. The girl is using 1 or more of the senses in Cartoon A but not in B.

b. The girl is using only 1 of the senses in Cartoon A but not in B.

c. The girl is recording observations in Cartoon A but not in B.

d. The girl is making an inference in Cartoon A but not in B.

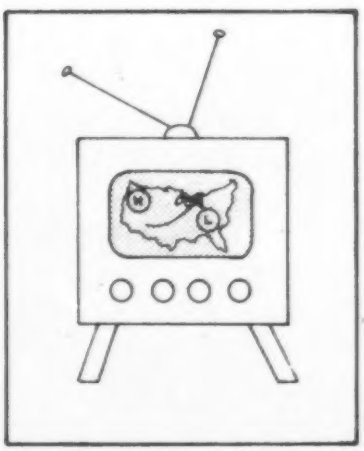
15. Look carefully at each of the 4 cartoons below.



Cartoon 1

Cartoon 2

Cartoon 3



Cartoon 4

Cartoon 1 is different from all the other cartoons in a certain way. How is it different?

a. Only Cartoon 1 shows someone <u>recording information</u>.

b. Only Cartoon 1 shows someone <u>using 1 or more of the senses</u>.

c. Only Cartoon 1 shows someone <u>making a guess</u>.

d. Only Cartoon 1 shows someone <u>making a prediction</u>.

16. Look carefully at each of the 4 cartoons below.

Cartoon 1

Cartoon 2

Cartoon 3

Cartoon 4

Cartoon 1 is different from all the other cartoons in a certain way. How is it different?

a. Only Cartoon 1 shows someone <u>using 1 or more of the senses</u>.

b. Only Cartoon 1 shows someone <u>recording information</u>.

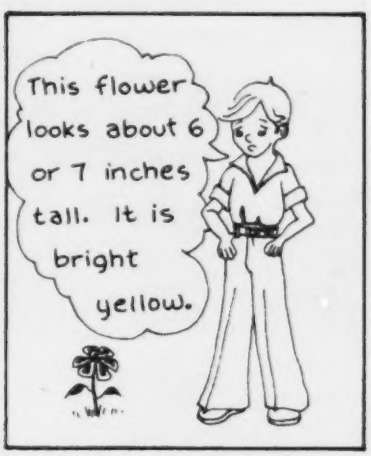
c. Only Cartoon 1 shows someone <u>examining carefully</u>.

d. Only Cartoon 1 shows someone <u>making a prediction</u>.

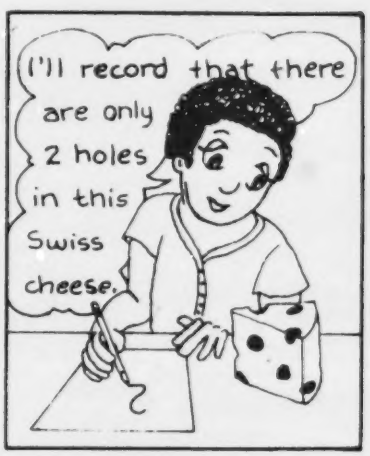
17. Look carefully at each of the 4 cartoons below.

Cartoon 1

Cartoon 2



Cartoon 3



Cartoon 4

Cartoon 1 is different from all the other cartoons in a certain way. How is it different?

a. Only Cartoon 1 shows someone looking at something.

b. Only Cartoon 1 shows someone using 1 or more of the senses.

c. Only Cartoon 1 shows someone recording information.

d. Only Cartoon 1 shows someone recording information accurately.

18. Which of the following is the best definition of observing scientifically?

    a. looking at something and writing down exactly what was seen

    b. using all of the 5 senses in examining things

    c. using 1 or more of the senses to examine things carefully and to record information accurately about what was observed

    d. using 1 or more of the senses to examine things carefully and to remember things accurately

APPENDIX F

INFORMATION ABOUT GROUPING FOR
DIFFERENTIATED INSTRUCTION IN EXPERIMENTAL SCHOOLS

INFORMATION ABOUT GROUPING FOR DIFFERENTIATED INSTRUCTION IN EXPERIMENTAL SCHOOLS

Teacher: At the beginning of each block of SAPA lessons (Observing, Inferring, or Space/Time), you should attempt to group the students on the basis of pre-test results and professional judgment.

It is suggested that the top 1/3 of the students be assigned to Group 1, the next 1/3 to Group 2, and the lower 1/3 to Group 3. The final decision as to group size and composition, however, rests with you.

Once grouped, the students should receive differentiated instruction. Provided below is a general description of the way instruction might proceed for the various groups:

GROUP 1

The students in this group will (presumably) proceed quickly through a SAPA lesson the first time it is taught. Teacher introduction and demonstration may be limited. Independent or small-group experimentation and recording of results is suggested. In presenting lesson content, the teacher may allow relatively more independence for group 1 students than for students in group 2 or 3.

The SAPA test may be given as soon as the student(s) is judged to be ready. Those students who demonstrate mastery of the SAPA content (generally, by achieving a score of 80% or higher on the test) may move on to enrichment activities, may choose to tutor another student, or may work on individual projects. In planning for the enrichment of group 1 students, be sure to

include the media center, supplementary texts (resource file for Houghton-Mifflin, Follett, and Addison-Wesley science materials), science kits, community projects, reports and demonstrations, etc.

Re-teach the SAPA content for those students who do not attain mastery (at the 80% level). Consider the use of supplementary texts as well as SAPA materials.

GROUP 2

The first time through a SAPA lesson, the teacher should give an introduction, teach important vocabulary words, give demonstrations, and provide opportunities for small-group observation and recording of results. The time required to proceed through the SAPA lesson may in some cases be greater for this group than for group 1. Essentially, activities will parallel those outlined for group 1: enrichment for those who master the SAPA content, and re-teaching for those who do not attain mastery. (For group 2, you may wish to use 80% as the criterion for "Mastery", or perhaps séttle for 70% depending upon student effort and lesson difficulty.)

GROUP 3

Of the three groups, it is expected that time for teaching the SAPA lesson first time through will be greatest for group 3. It is estimated that almost all of the time allotted for a given lesson will be spent in teacher-led activities: introducing the lesson, teaching and reviewing vocabulary, doing experiments in large groups (teacher plus a few volunteers) and discussing results. Where written reports are required, the teacher may write on the blackboard and have all students copy the material rather than having them write reports independently.

A variety of large-group experiments and structured activities should be provided for this group of students. Following the teaching of the SAPA lesson and the administration of the SAPA test, additional reading in supplementary texts and/or individualized instruction with a tutor may be appropriate activities, if time permits. For those students who fail to master the SAPA material, it may be more appropriate to turn to lower level science texts (refer to resource file) rather than re-teach the SAPA lesson.

The teacher should give careful consideration to the criterion for mastery level performance; 70% or even lower may be realistic for group 3 students.

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